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(12) United States Patent
Yokoyama

(10) **Patent No.: US 9,287,625 B2**
(45) **Date of Patent: Mar. 15, 2016**

(54) **STACK-TYPE INDUCTOR ELEMENT AND METHOD OF MANUFACTURING THE SAME, AND COMMUNICATION DEVICE**

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(72) Inventor: **Tomoya Yokoyama**, Nagaokakyo (JP)

(73) Assignee: **Murata Manufacturing Co., Ltd.**, Kyoto (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/205,406**

(22) Filed: **Mar. 12, 2014**

(65) **Prior Publication Data**

US 2014/0266949 A1 Sep. 18, 2014

(30) **Foreign Application Priority Data**

Mar. 18, 2013 (JP) 2013-054613
Feb. 6, 2014 (JP) 2014-021305

(51) **Int. Cl.**

H01Q 1/00	(2006.01)
H01Q 7/06	(2006.01)
H01F 41/04	(2006.01)
H01F 17/00	(2006.01)

(52) **U.S. Cl.**

CPC ***H01Q 7/06*** (2013.01); ***H01F 17/0013*** (2013.01); ***H01F 41/041*** (2013.01); *H01F 2017/0066* (2013.01); *Y10T 29/4902* (2015.01)

(58) **Field of Classification Search**

CPC H01Q 7/06; H01Q 7/08; H01Q 1/38
USPC 343/787, 850, 866; 336/117, 222
See application file for complete search history.

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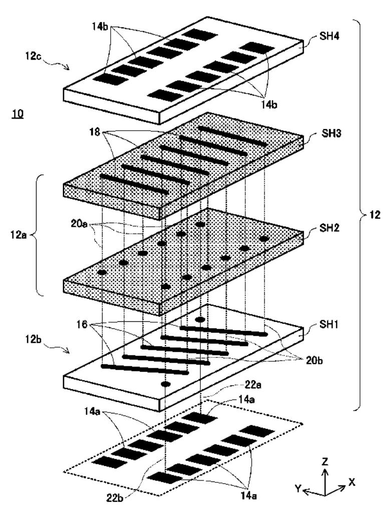
Primary Examiner — Dameon E Levi
Assistant Examiner — Collin Dawkins
(74) *Attorney, Agent, or Firm* — Keating & Bennett, LLP

(57) **ABSTRACT**

A stack-type inductor element includes a stack including a magnetic element layer, a coil conductor pattern provided in the stack and the magnetic element layer defines a magnetic element core, a plurality of first pad electrodes provided on one main surface of the stack, and a plurality of second pad electrodes provided on the other main surface of the stack so as to be symmetric to the plurality of first pad electrodes. One end and the other end of the coil conductor pattern are electrically connected to two of the plurality of first pad electrodes, respectively, and the plurality of second pad electrodes are all electrically open.

11 Claims, 27 Drawing Sheets



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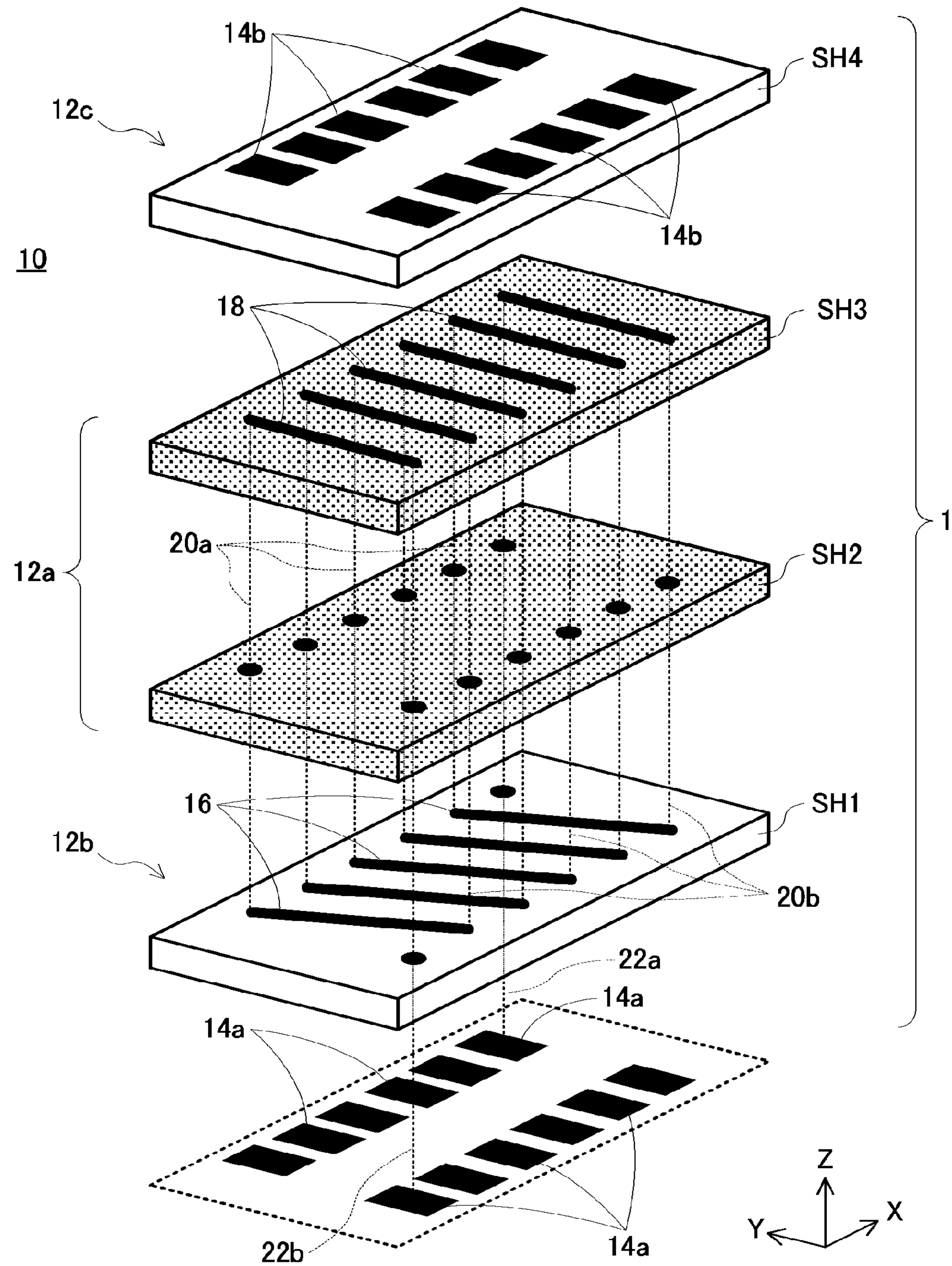
* cited by examiner

FIG.1



14b
12c
SH4
14b
10
18
SH3
12a
20a
SH2
12
16
12b
SH1
20b
22a
14a
14a
22b
14a
Z
Y
X

FIG.2A

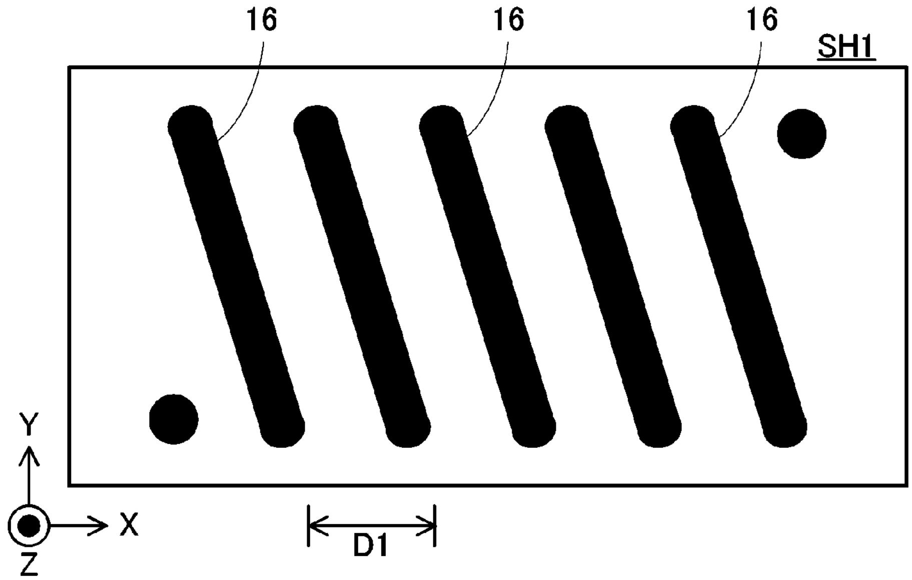


FIG.2B

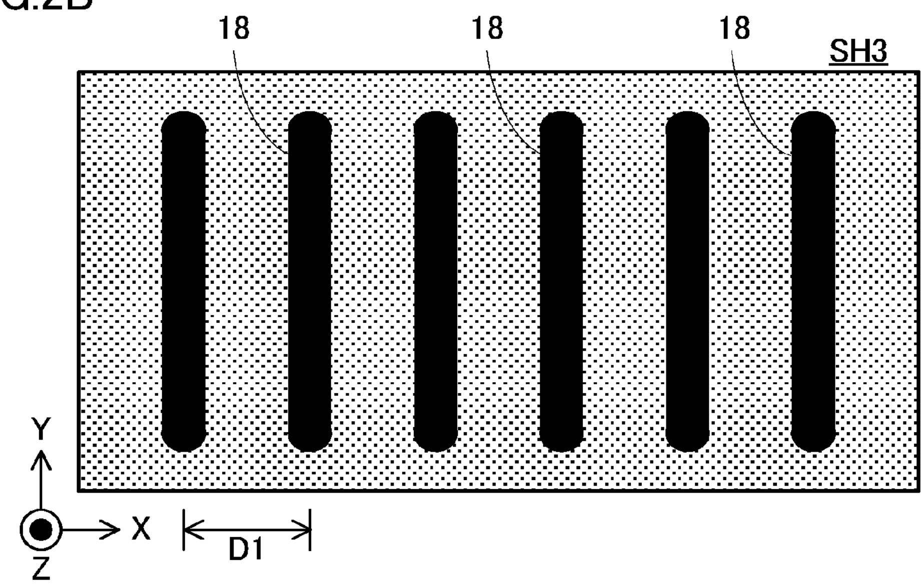


FIG.3A

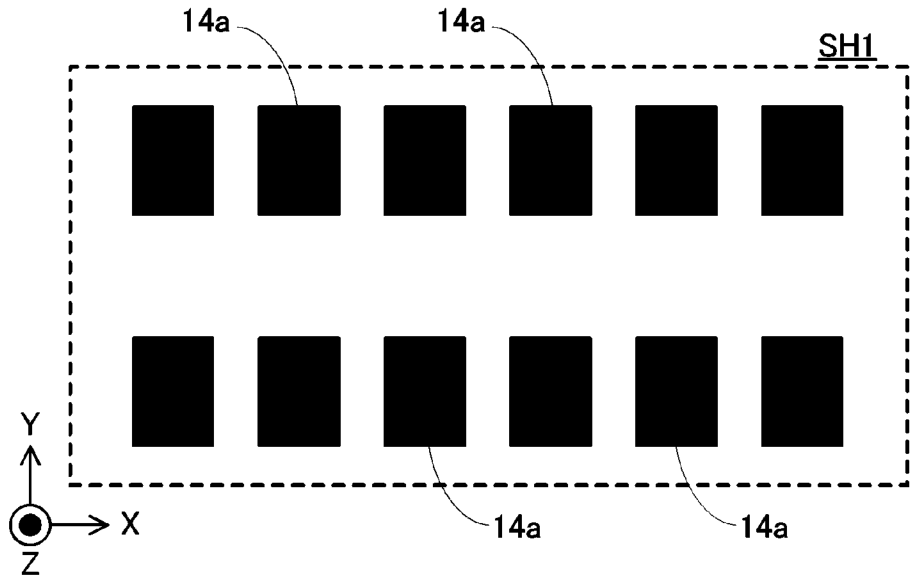


FIG.3B

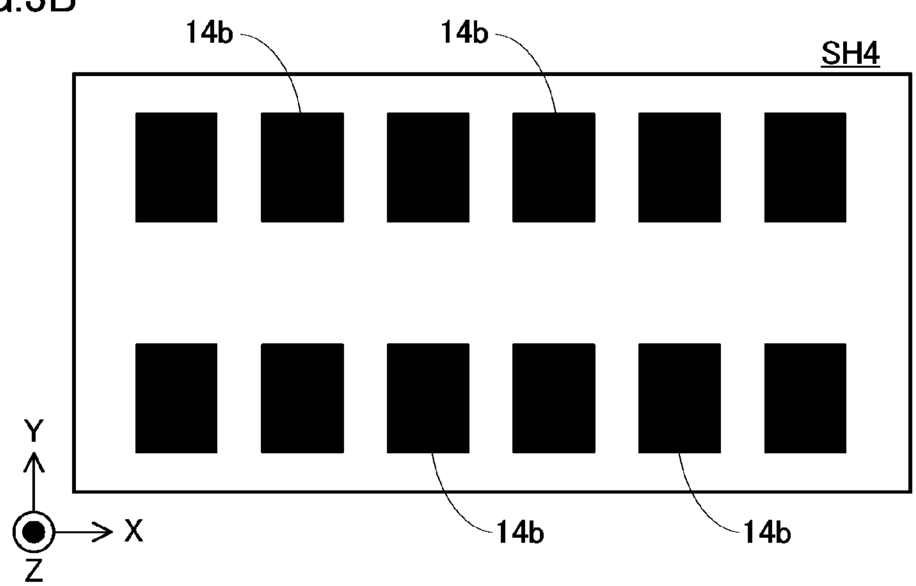


FIG.4

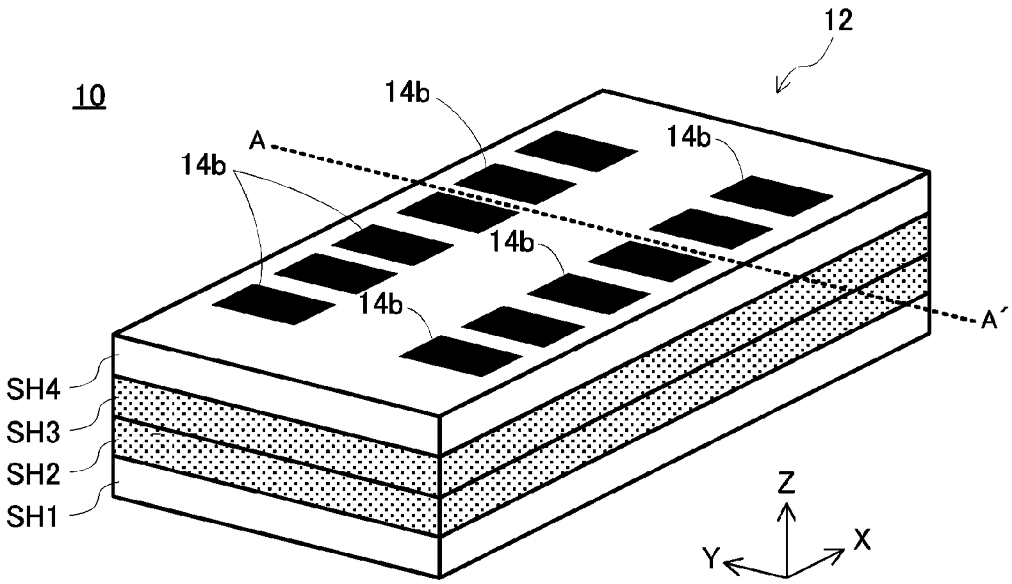

12
10
14b
A
14b
14b
14b
14b
A´
SH4
SH3
SH2
SH1
Z
X
Y

FIG.5

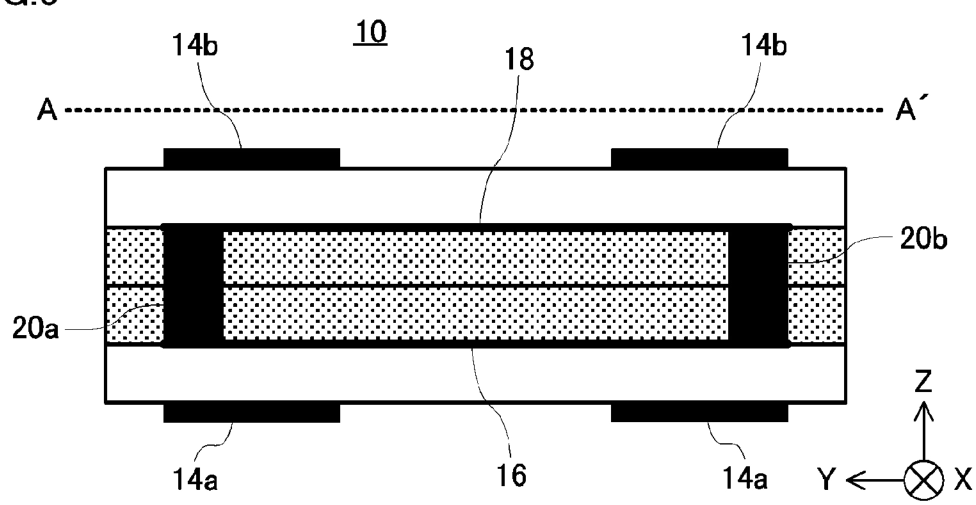

10
14b
18
14b
A
A´
20b
20a
Z
14a
16
14a
Y
X

FIG.6A

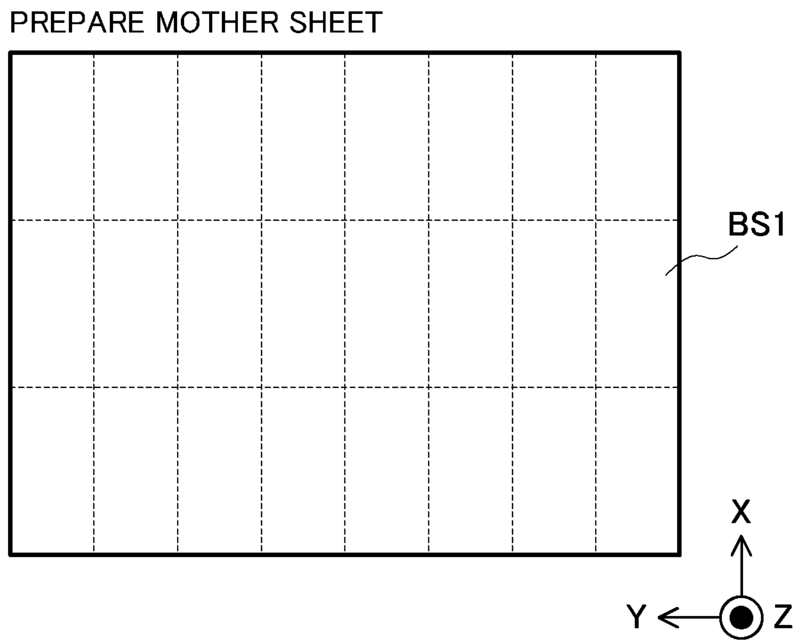

PREPARE MOTHER SHEET
BS1
X
Y
Z

FIG.6B

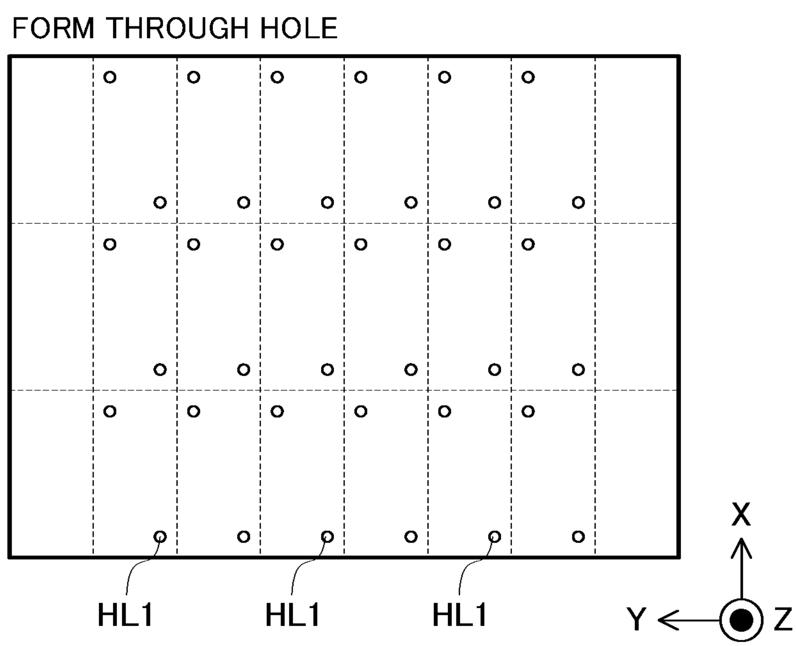

FORM THROUGH HOLE
HL1
HL1
HL1
X
Y
Z

FIG.7A

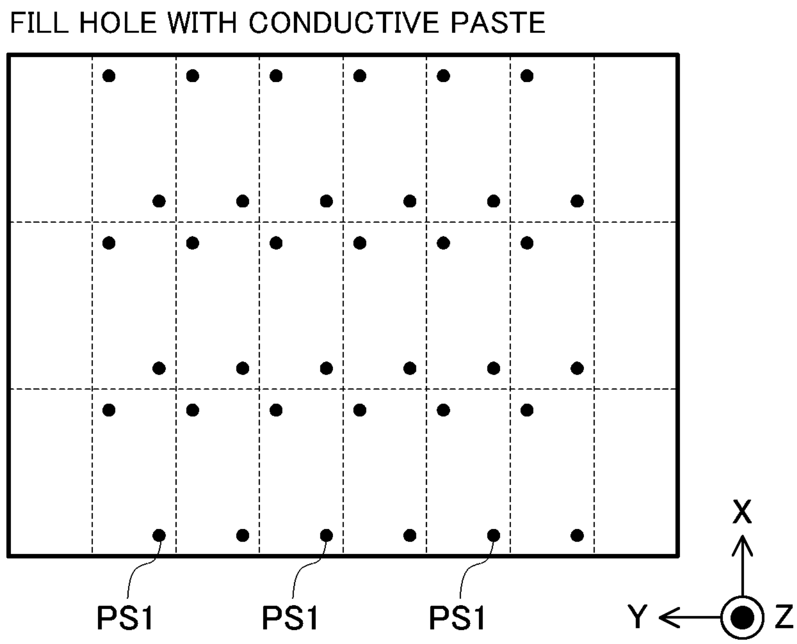

FILL HOLE WITH CONDUCTIVE PASTE
PS1
PS1
PS1
X
Y
Z

FIG.7B

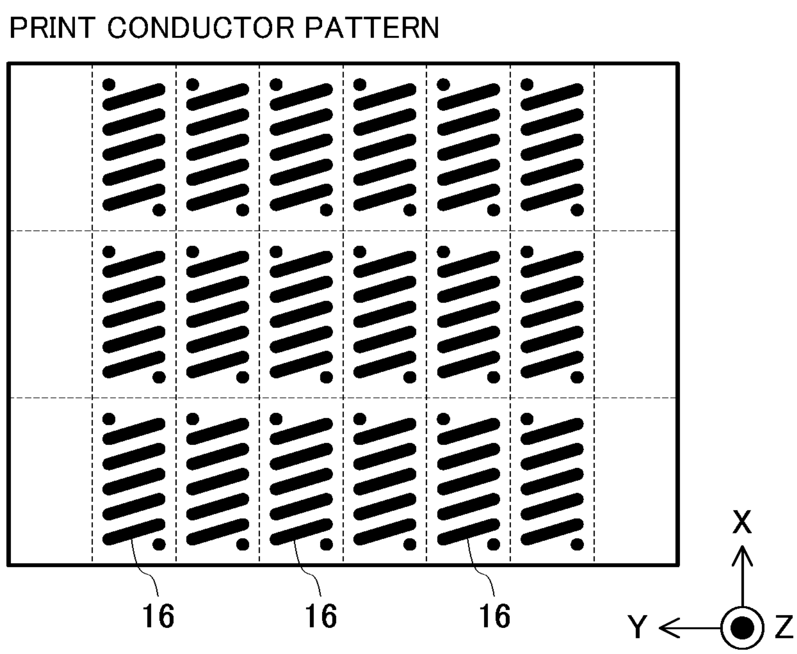

PRINT CONDUCTOR PATTERN
16
16
16
X
Y
Z

FIG.8A

PREPARE MOTHER SHEET

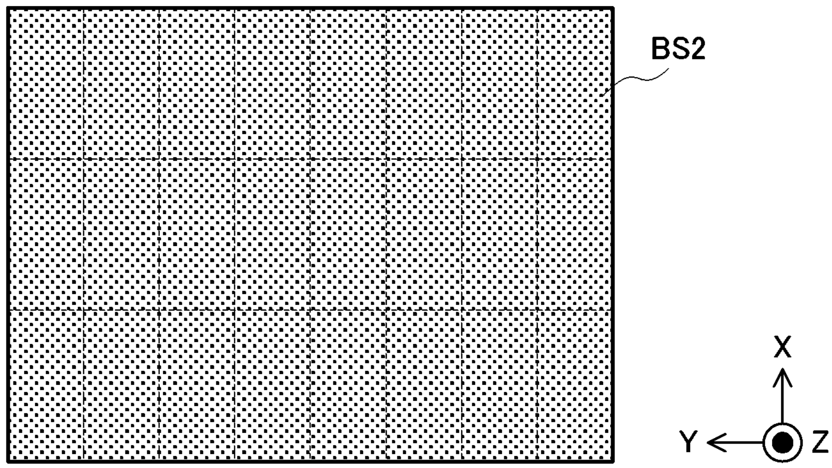


FIG.8B

FORM THROUGH HOLE

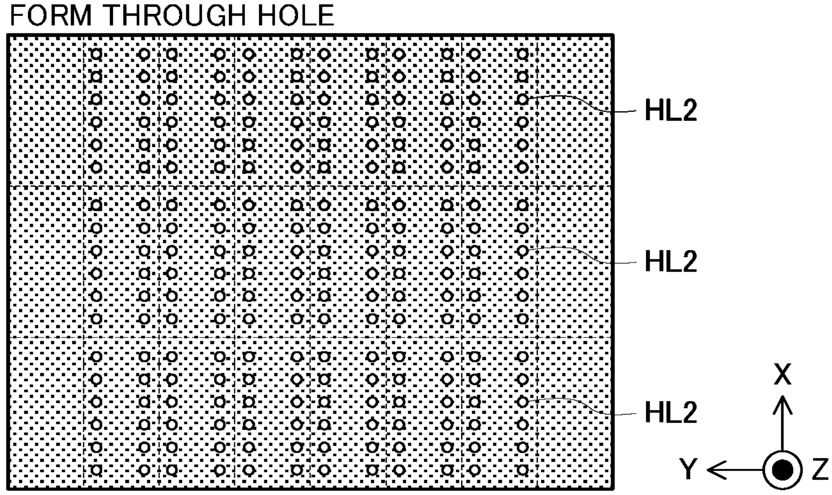


FIG.8C

FILL HOLE WITH CONDUCTIVE PASTE

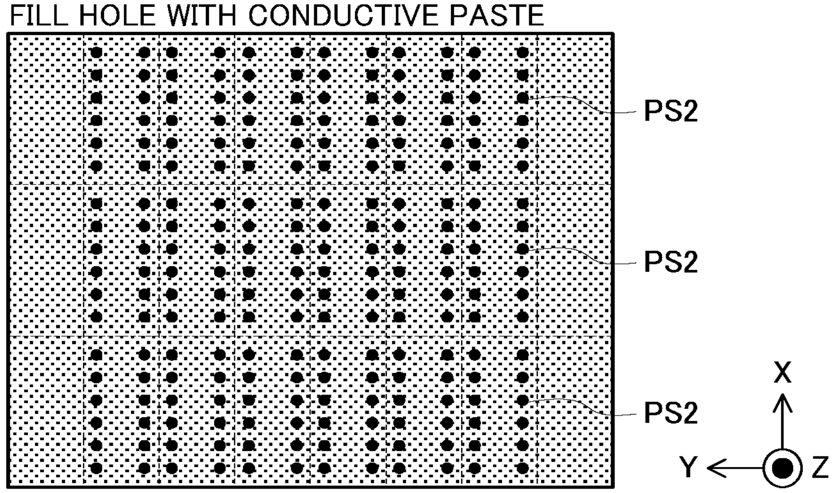


FIG.9A

PREPARE MOTHER SHEET

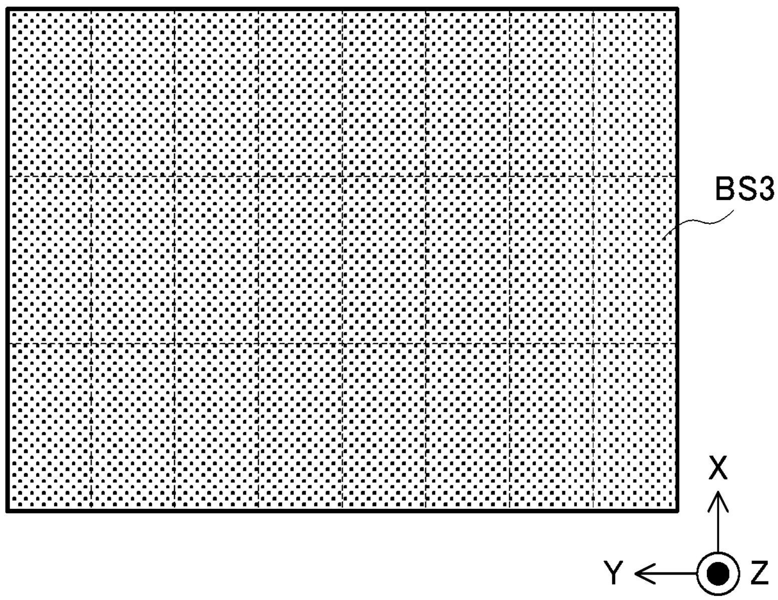


FIG.9B

FORM THROUGH HOLE

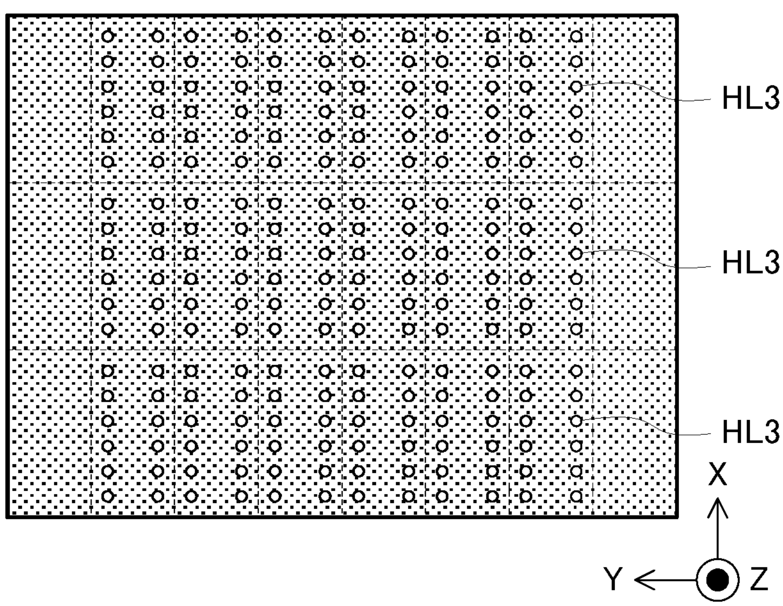


FIG.10A

FILL HOLE WITH CONDUCTIVE PASTE

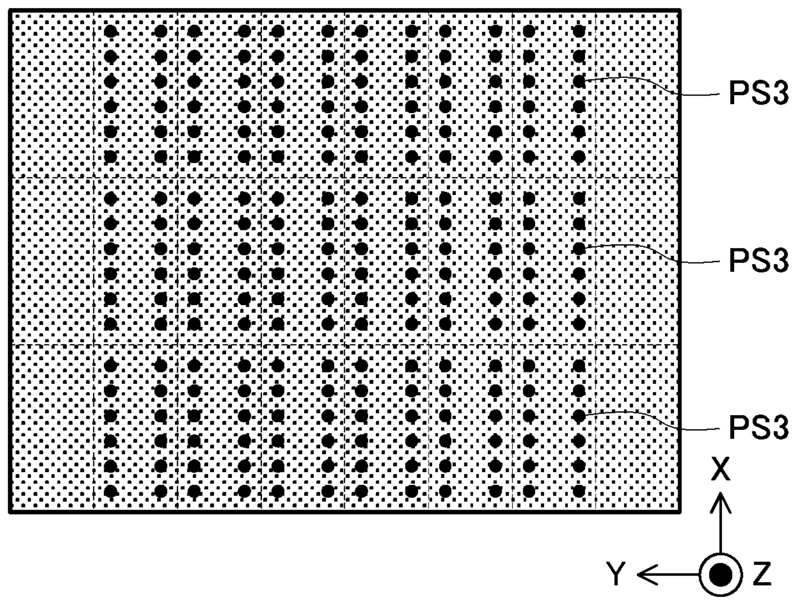


FIG.10B

PRINT CONDUCTOR PATTERN

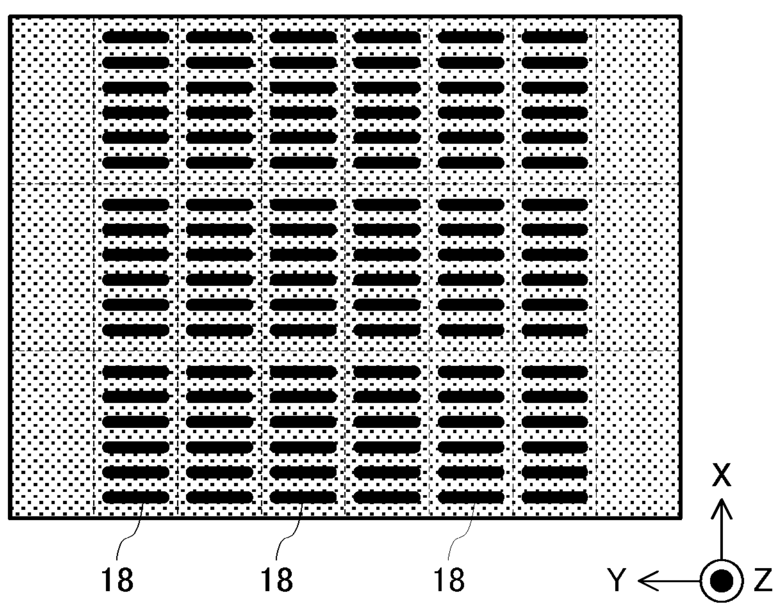


FIG.11A

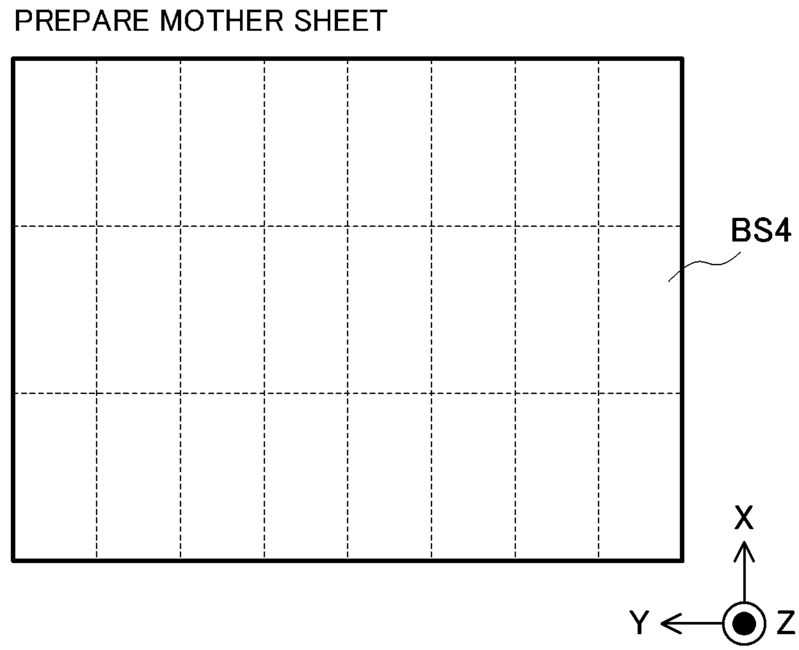


FIG.11B

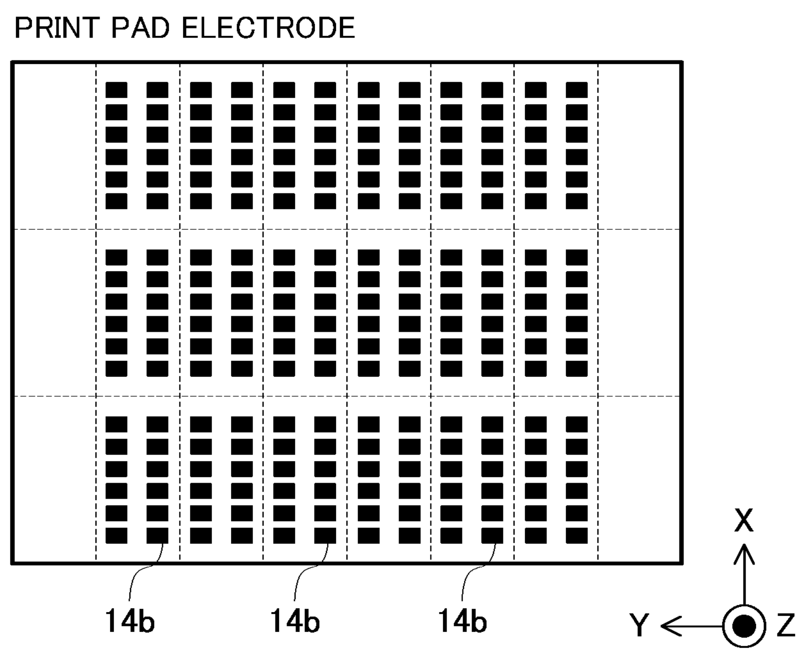


FIG.12

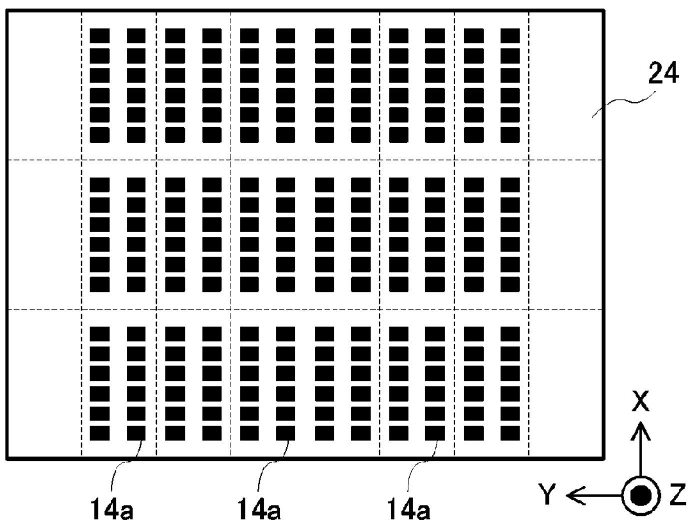


FIG.13A

STACK AND PRESS-BOND SHEETS

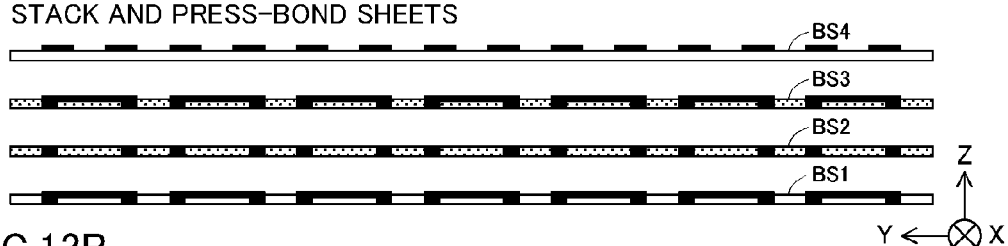


FIG.13B

PREPARE PET FILM

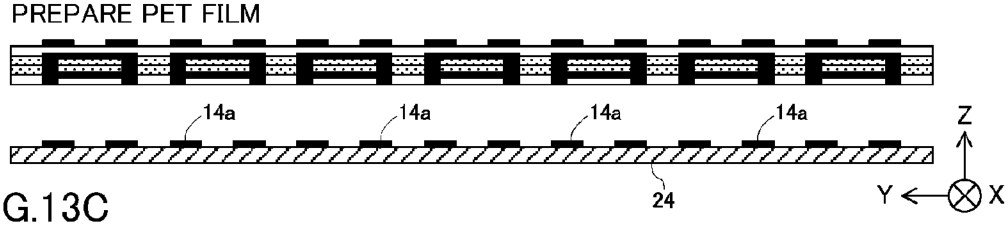


FIG.13C

TRANSFER

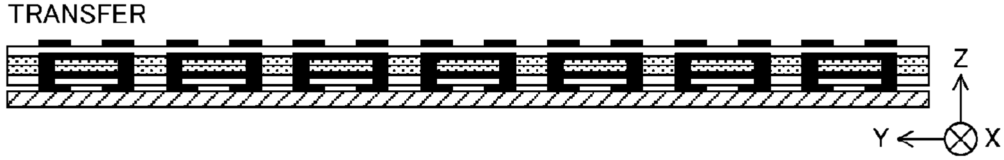


FIG.14A

PEEL OFF PET FILM

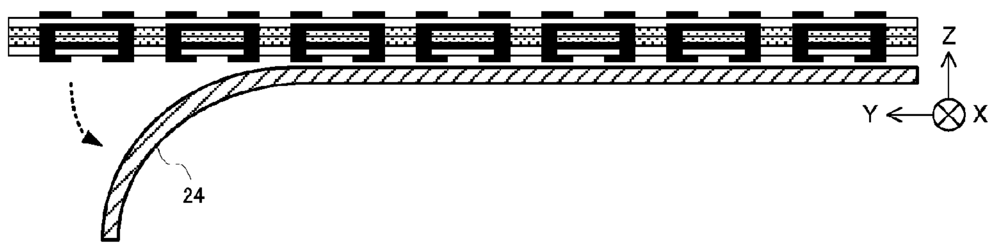


FIG.14B

FIRING

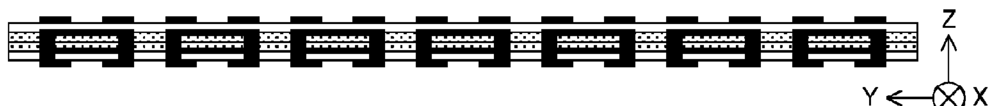


FIG.14C

PRIMARY SCRIBING

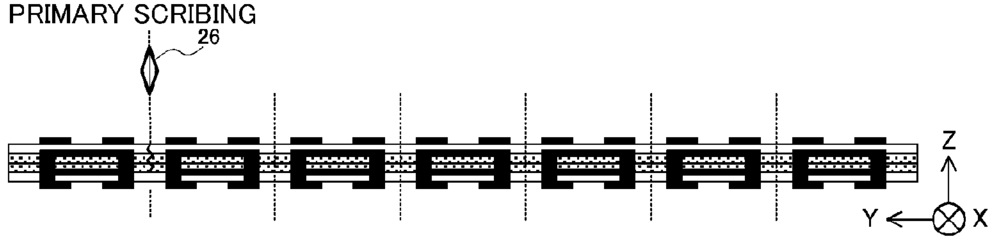


FIG.14D

SECONDARY SCRIBING

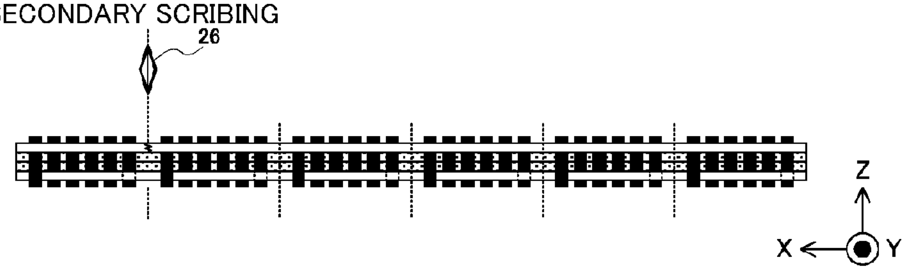


FIG.15A

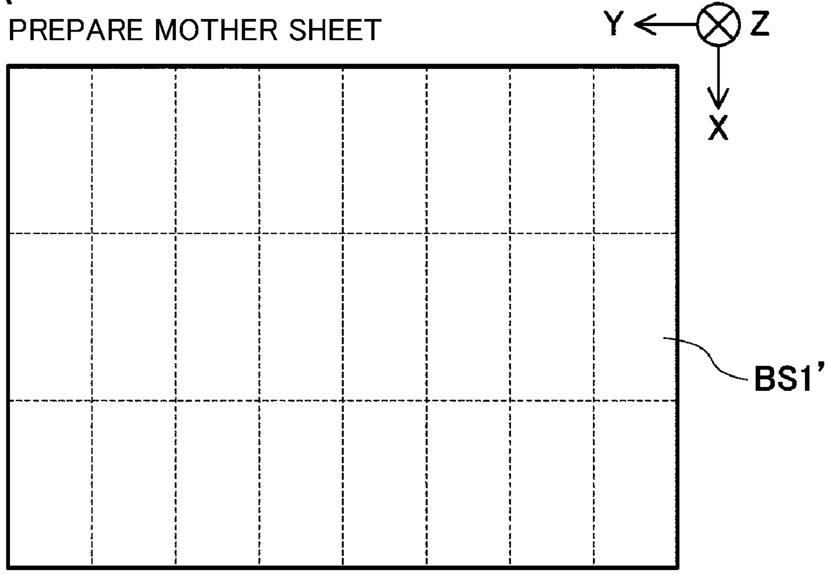


FIG.15B

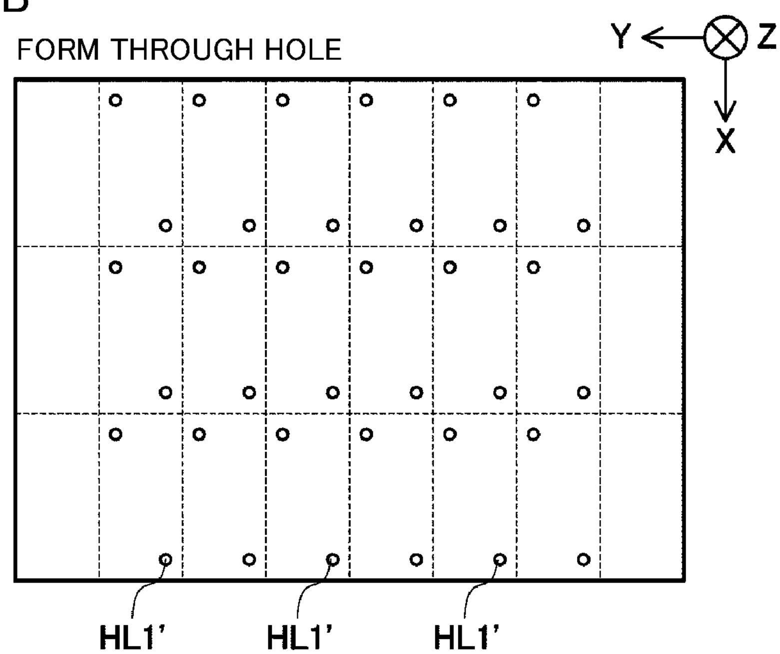


FIG.16A

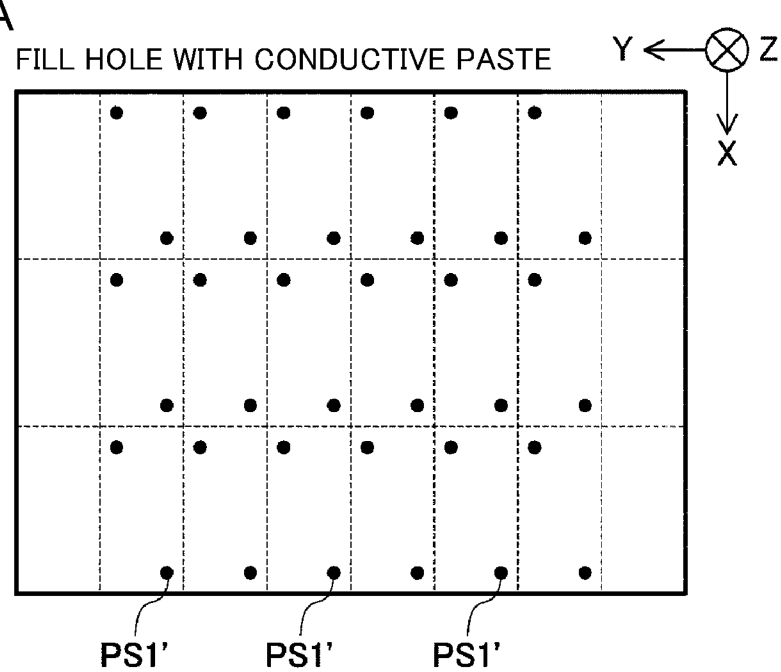


FIG.16B

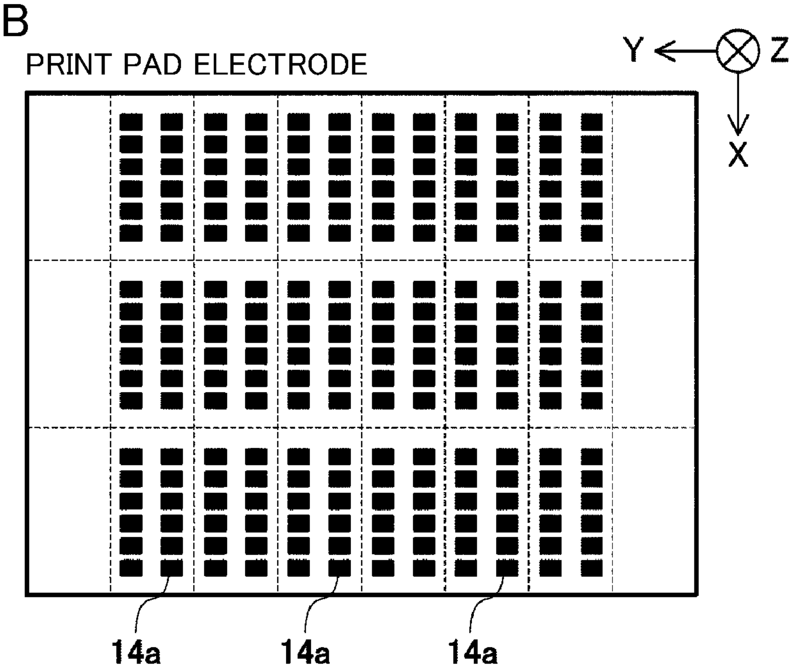


FIG.17A

PREPARE MOTHER SHEET

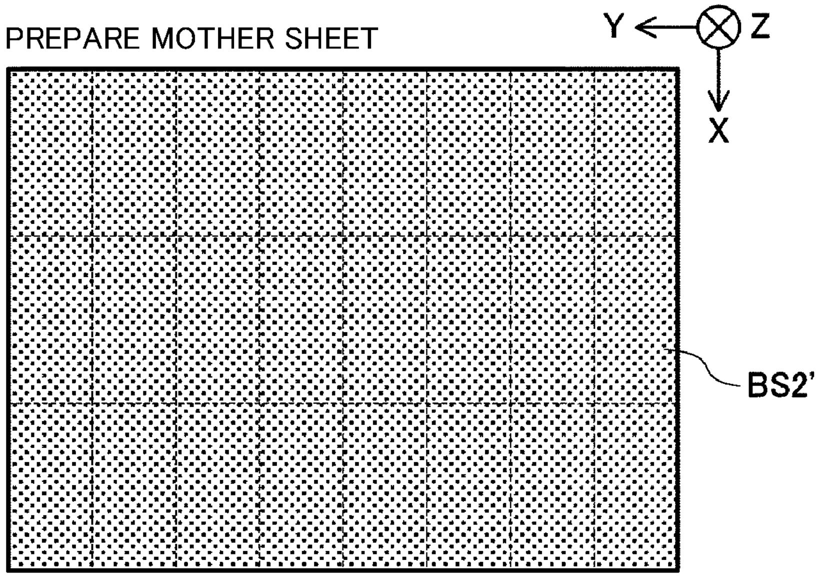


FIG.17B

FORM THROUGH HOLE

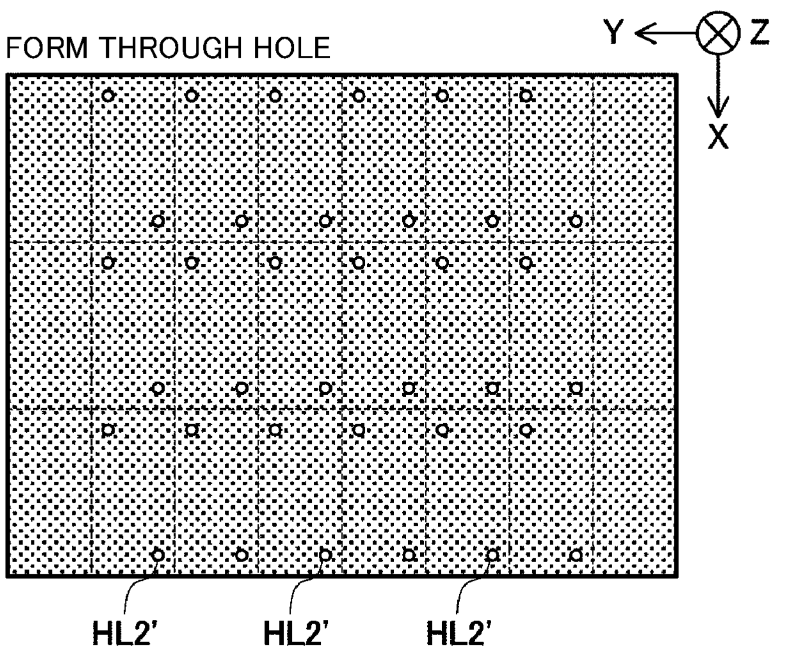


FIG.18A

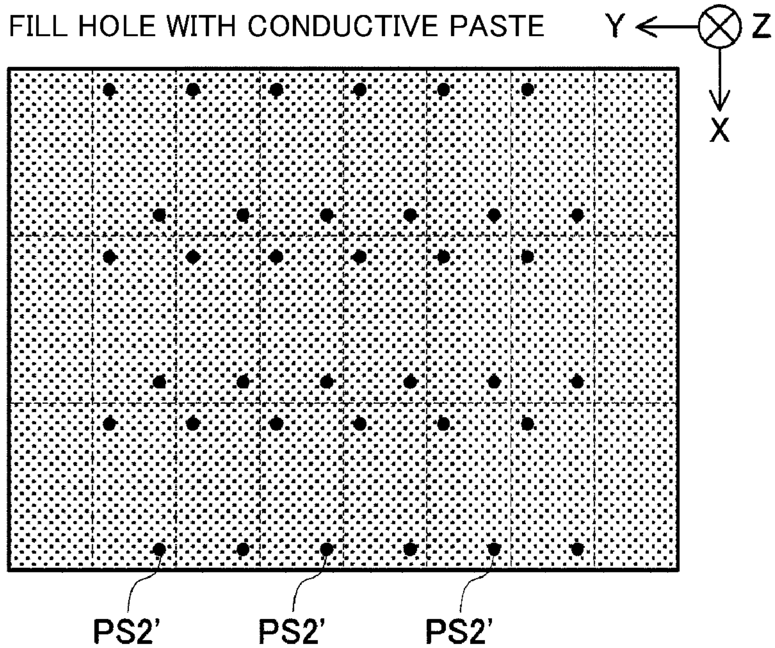


FIG.18B

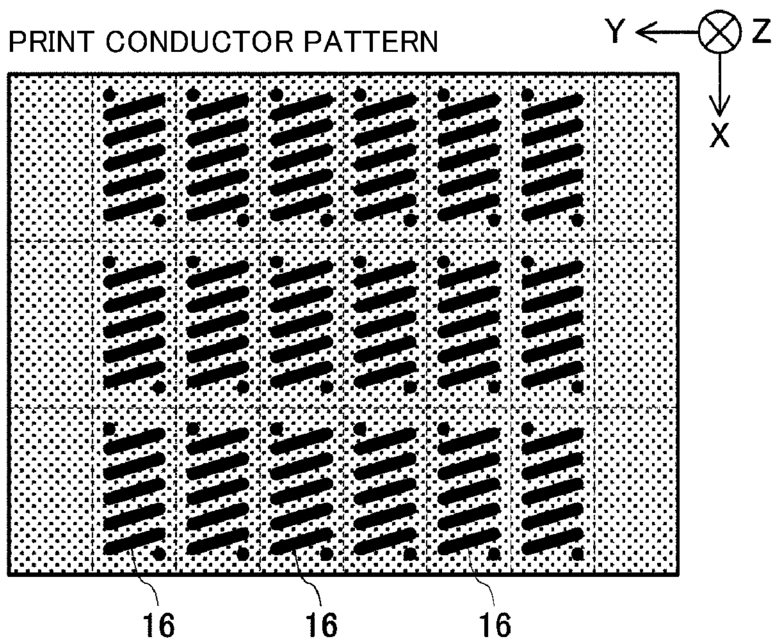


FIG.19A

PREPARE MOTHER SHEET

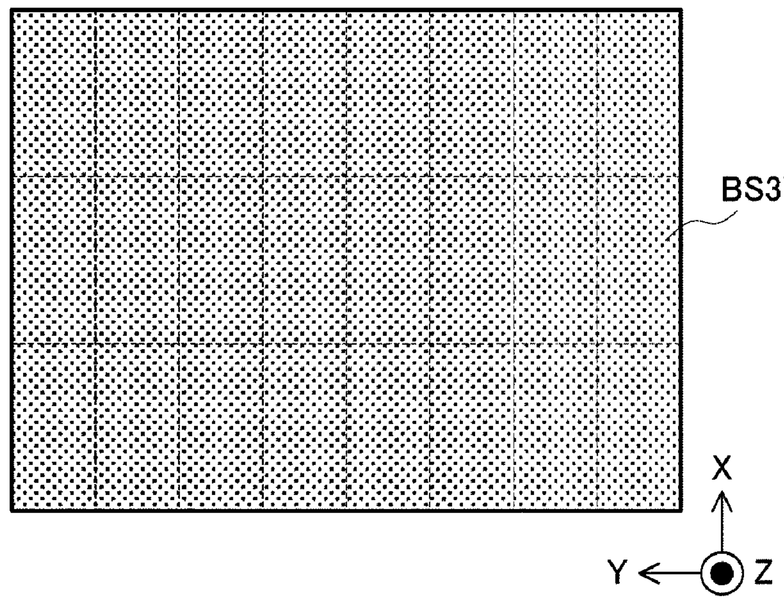


FIG.19B

FORM THROUGH HOLE

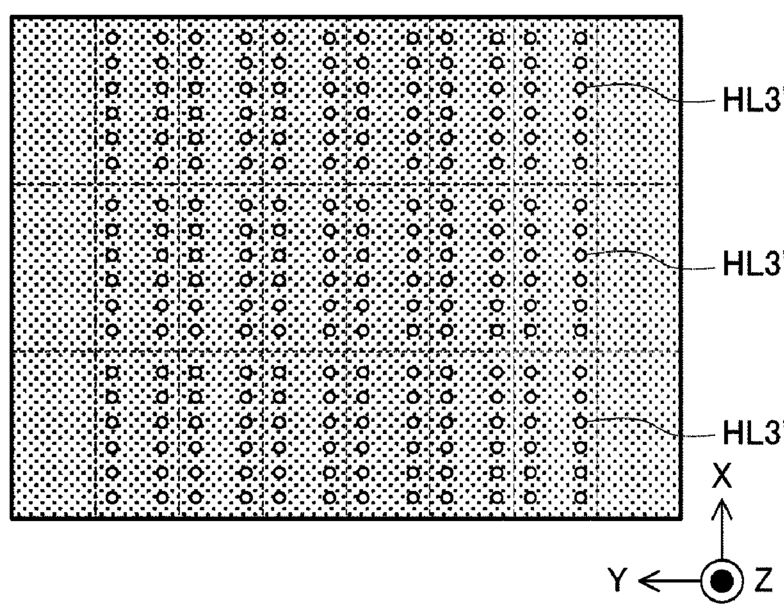


FIG.20A

FILL HOLE WITH CONDUCTIVE PASTE

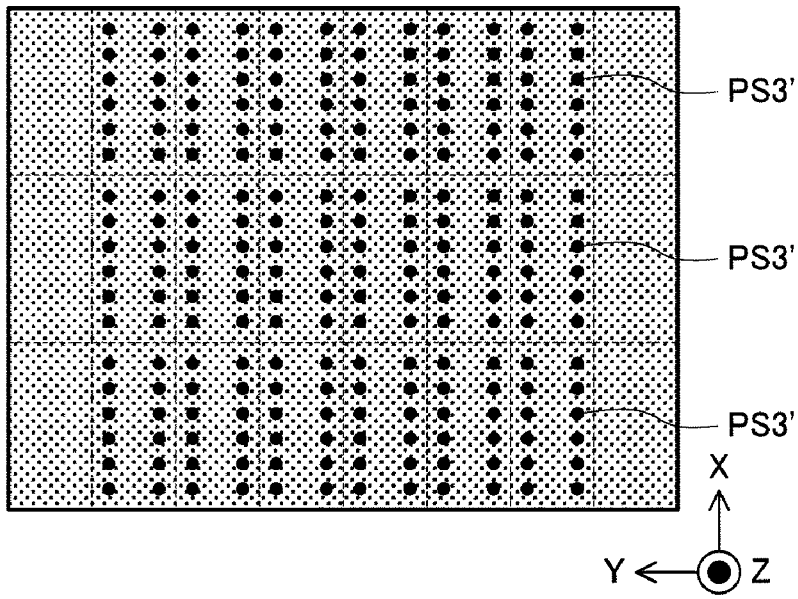


FIG.20B

PRINT CONDUCTOR PATTERN

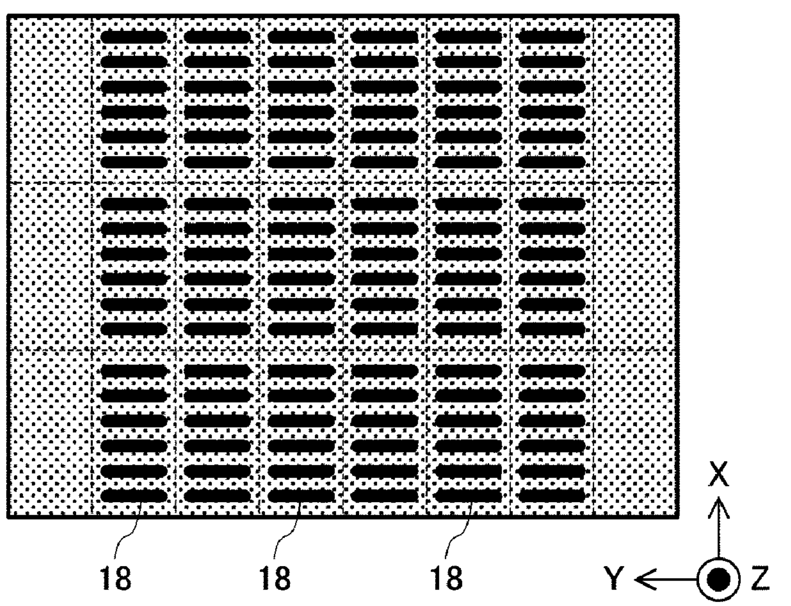


FIG.21A

PREPARE MOTHER SHEET

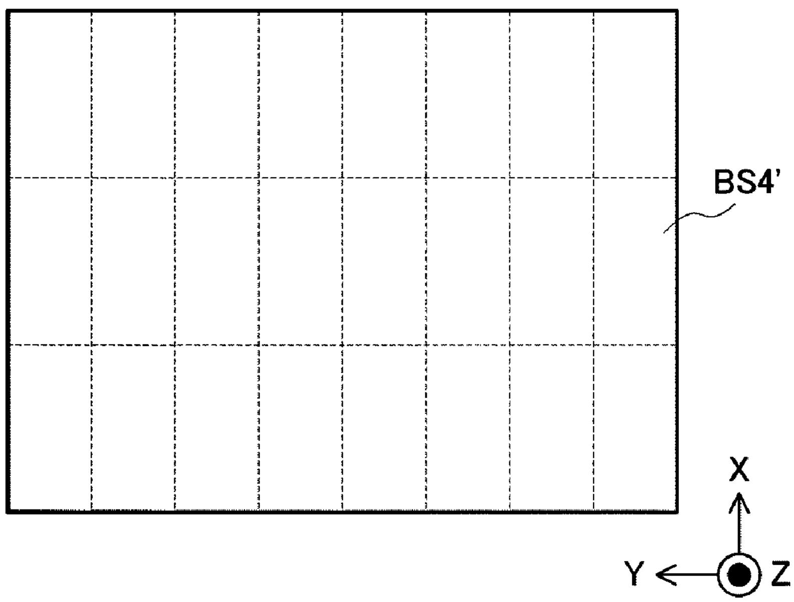


FIG.21B

PRINT PAD ELECTRODE

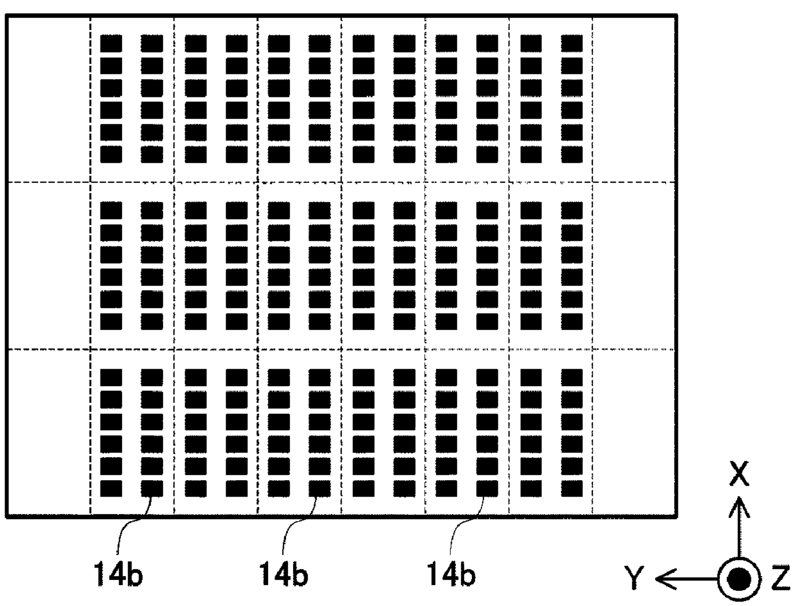


FIG.22A

FIG.22B

FIG.22C

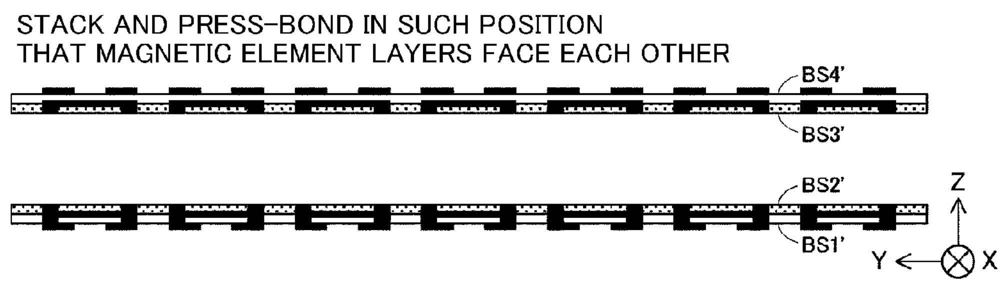


FIG.23A

FIRING

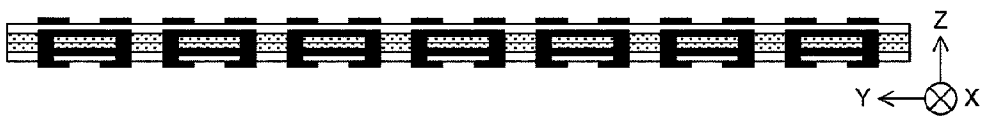


FIG.23B

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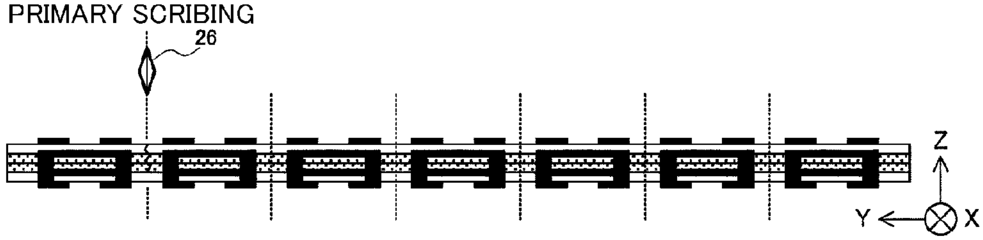


FIG.23C

SECONDARY SCRIBING

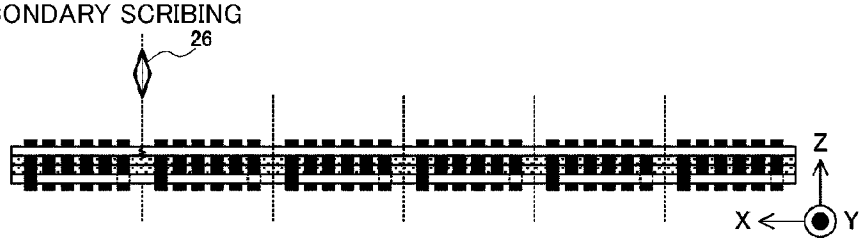


FIG.24

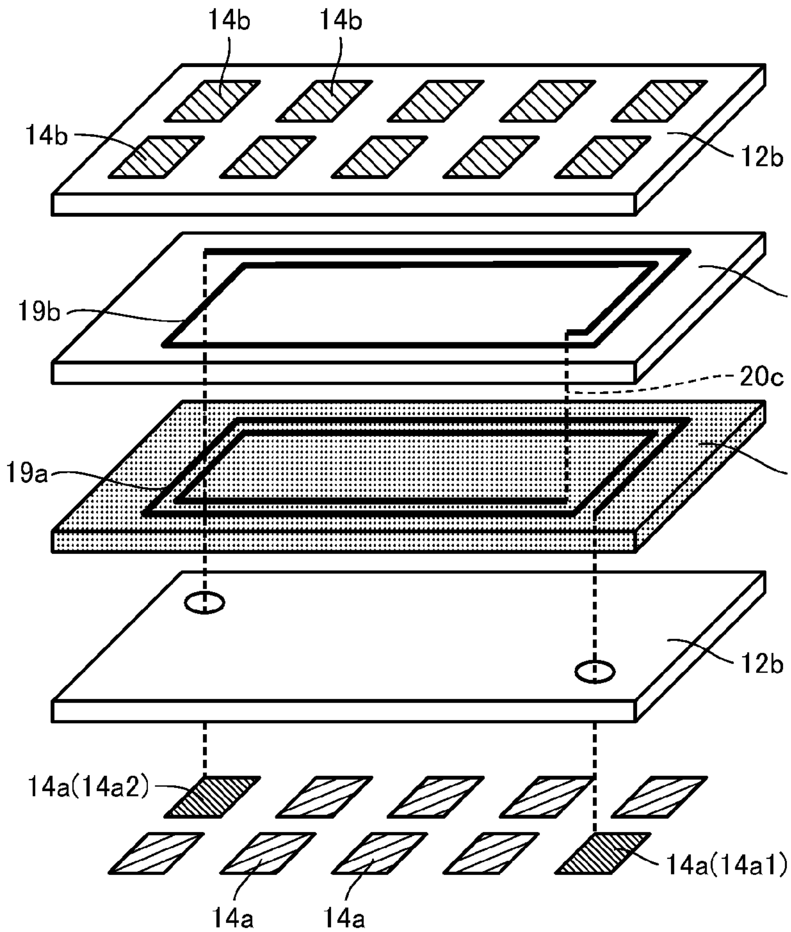
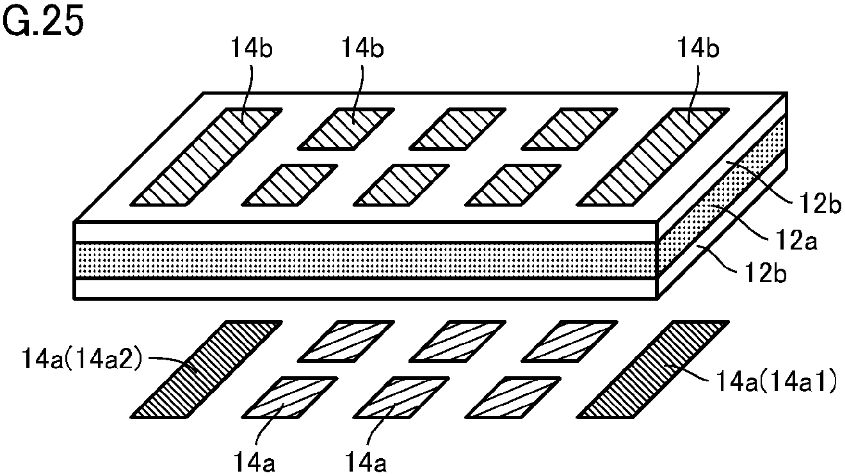

14b
14b
14b
12b
19b
12b
20c
19a
12a
12b
14a(14a2)
14a(14a1)
14a
14a

FIG.25


14b
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14b
12b
12a
12b
14a(14a2)
14a(14a1)
14a
14a

FIG.26

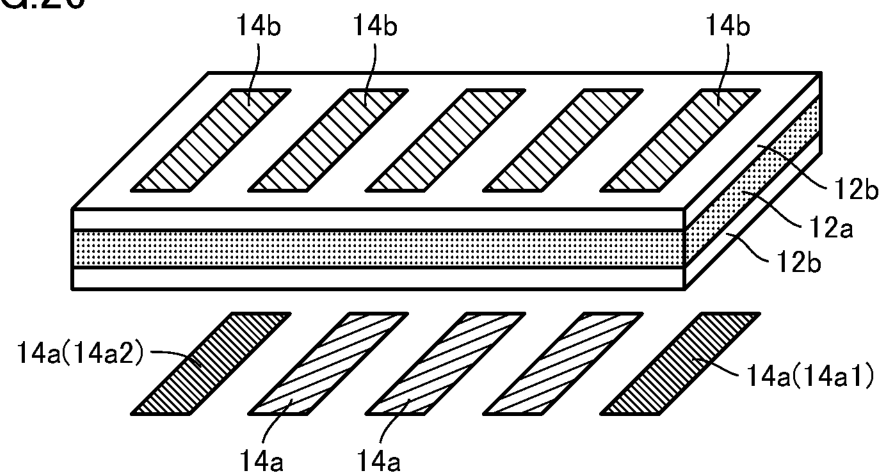
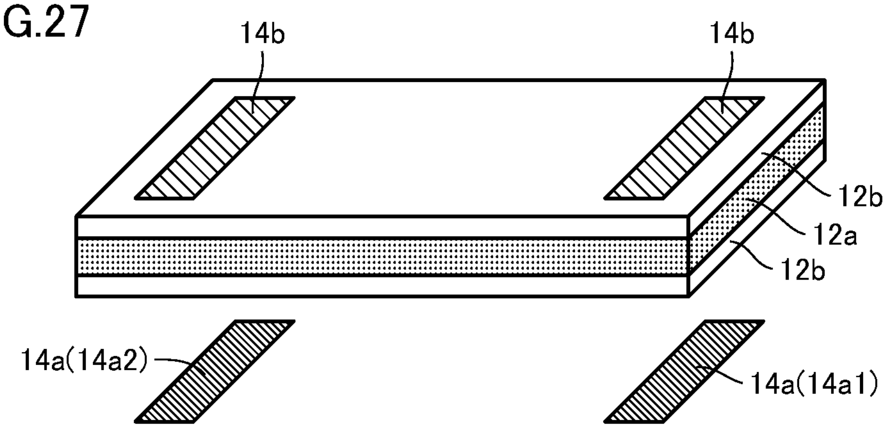

14b
14b
14b
12b
12a
12b
14a(14a2)
14a(14a1)
14a
14a

FIG.27


14b
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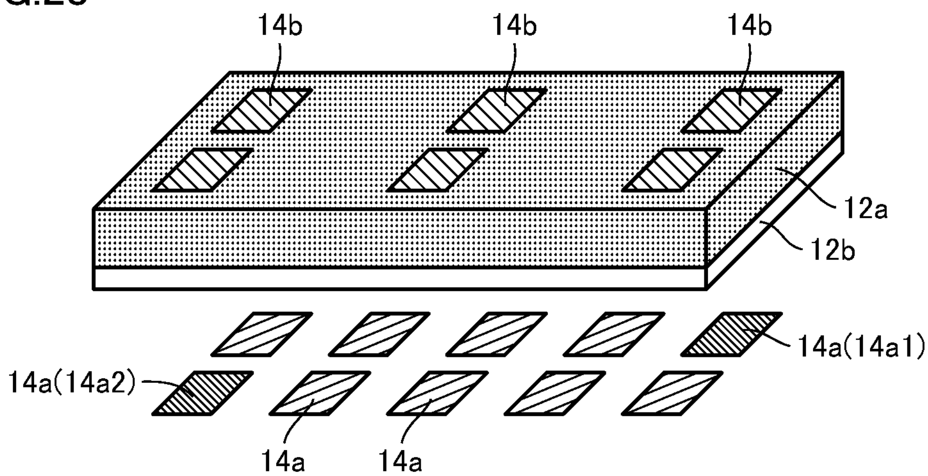
12a
12b
14a(14a2)
14a(14a1)

FIG.28


14b
14b
14b
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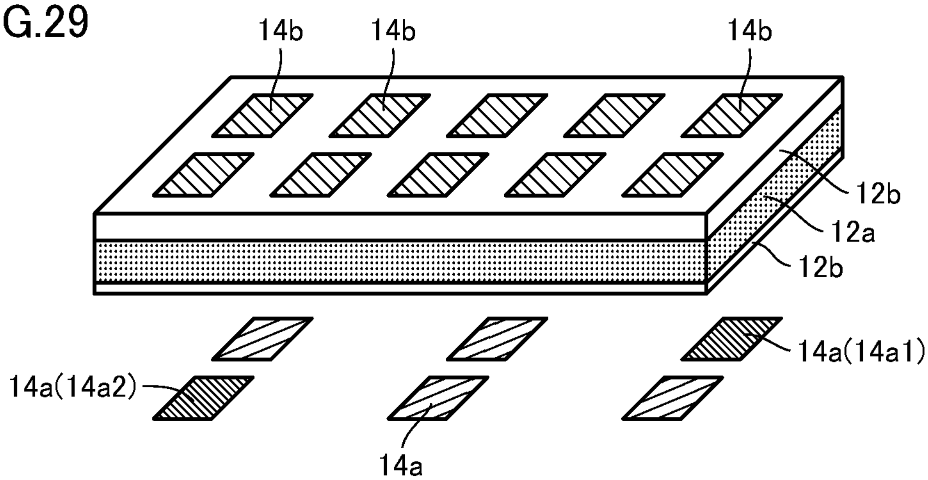
12b
14a(14a1)
14a(14a2)
14a
14a

FIG.29


14b
14b
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12a
12b
14a(14a1)
14a(14a2)
14a

FIG.30

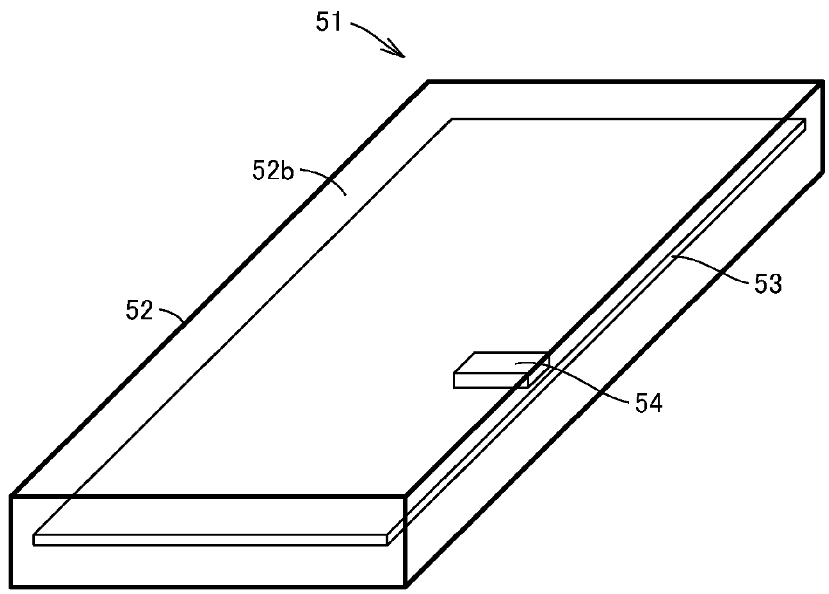


FIG.31

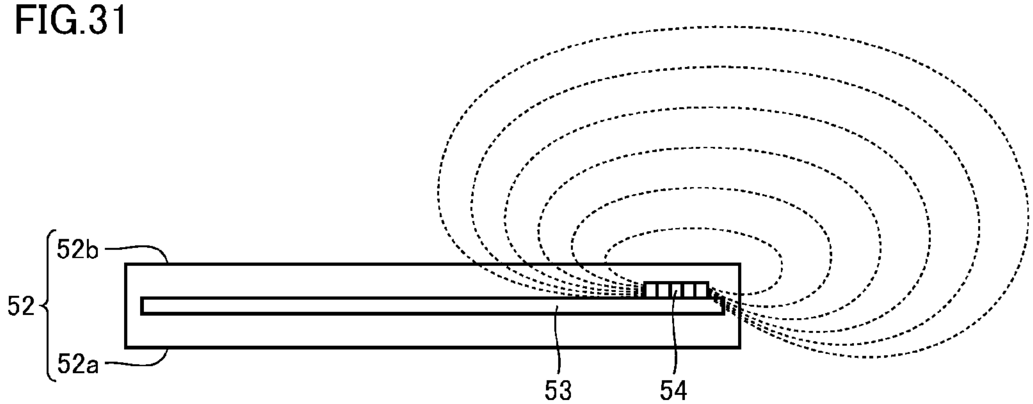


FIG.32

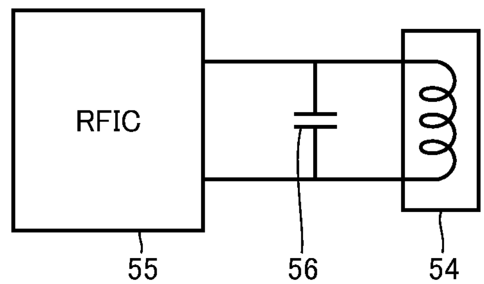


FIG.33

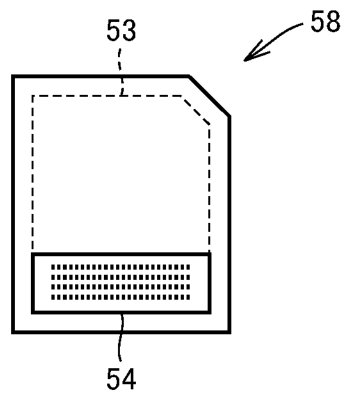
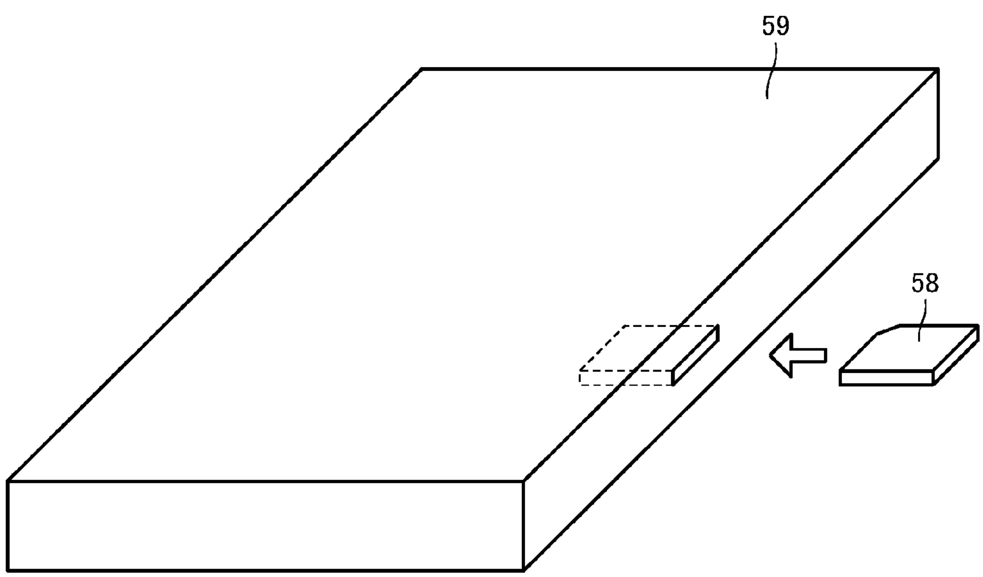


FIG.34



STACK-TYPE INDUCTOR ELEMENT AND METHOD OF MANUFACTURING THE SAME, AND COMMUNICATION DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a stack-type inductor element, and particularly to a stack-type inductor element including a stack obtained by stacking a magnetic element layer and a non-magnetic element layer and a conductor pattern located on opposing surfaces of the magnetic element layer which defines a portion of the inductor.

The present invention also relates to a manufacturing method of manufacturing such a stack-type inductor element.

The present invention further relates to a communication device including such a stack-type inductor element.

2. Description of the Related Art

Japanese Patent Laying-Open No. 2009-111197 (see, for example, paragraph 0052) and Japanese Patent Laying-Open No. 2009-231331 (see, for example, paragraphs 0033 and 0040) disclose one example of a stack-type inductor element of this type and a method of manufacturing the same. According to Japanese Patent Laying-Open No. 2009-111197, an adhesive film is provided on at least one surface of a sintered ferrite substrate. In addition, in order to provide a stack with a bending property, a fracture is formed in the substrate. Here, a fracture lowers permeability, however, permeability varies depending on a state of the fracture. Therefore, grooves are formed in the substrate with regularity and a fracture is formed in this groove portion. Thus, magnetic characteristics after formation of a fracture can be stabilized while a bending property is provided.

According to Japanese Patent Laying-Open No. 2009-231331, in order to divide a ceramic substrate into individual pieces of a stack, a division groove is formed in the ceramic substrate. Specifically, the division groove is formed by moving a scribing blade pressed against the other main surface of the ceramic substrate with a desired pressure. In succession, a roller pressed against one main surface of the ceramic substrate with a protection sheet being interposed is moved along the ceramic substrate. Thus, the ceramic substrate deforms to open the division groove, so that the ceramic substrate is divided along the division groove.

When a groove is formed in a substrate in a stage prior to firing, warpage is caused due to asymmetry between one main surface and the other main surface forming the substrate. This warpage may impair coplanarity of each element obtained by breakage (division into individual pieces) of the substrate and may become a factor interfering decrease in thickness.

SUMMARY OF THE INVENTION

Therefore, preferred embodiments of the present invention provide a stack-type inductor element having a smaller thickness and a method of manufacturing the same, and a communication device.

According to a preferred embodiment of the present invention, a stack-type inductor element includes a stack including a magnetic element layer, a coil conductor pattern provided in the stack and including the magnetic element layer as a magnetic element core, a plurality of first pad electrodes provided on one main surface of the stack, and a plurality of second pad electrodes provided on the other main surface of the stack to be symmetric to the plurality of first pad electrodes, one end and the other end of the coil conductor pattern are electrically

connected to two of the plurality of first pad electrodes, respectively, and the plurality of second pad electrodes are all electrically open.

Preferably, the stack has a rectangular or substantially rectangular shape when viewed in a direction of stack of the stack and the plurality of first pad electrodes are arranged in two rows along a longitudinal direction of the stack.

Preferably, the number of the first pad electrodes is three or more and a pad electrode not connected to the coil conductor pattern of the plurality of first pad electrodes is each electrically open.

Preferably, the stack includes non-magnetic element layers arranged to be superimposed on opposing main surfaces of the magnetic element layer.

A method of manufacturing a stack-type inductor element according to another preferred embodiment of the present invention is a method of manufacturing a stack-type inductor element by dividing into division units, a substrate assembly including a structure sandwiching a magnetic element layer between a first outermost layer and a second outermost layer, the method including a first step of forming a plurality of first via holes passing through the first outermost layer, a second step of forming a plurality of first conductor patterns on an upper surface of the first outermost layer or a lower surface of the magnetic element layer, a third step of forming a plurality of second via holes passing through the magnetic element layer, a fourth step of forming a plurality of second conductor patterns on an upper surface of the magnetic element layer or a lower surface of the second outermost layer, a fifth step of performing an operation for forming a plurality of first pad electrodes on a lower surface of the first outermost layer and connecting two first pad electrodes to two respective points of the plurality of first conductor patterns through two first via holes for each division unit, a sixth step of forming a plurality of second pad electrodes on an upper surface of the second outermost layer so as to be symmetric to the plurality of first pad electrodes, and a seventh step of fabricating a plurality of inductors by spirally connecting the plurality of first conductor patterns and the plurality of second conductor patterns through the plurality of second via holes for each division unit.

Preferably, a ninth step of applying a blade of a scriber to a line defining the division unit and forming a groove in a longitudinal direction and a direction of a short side of the substrate assembly is further provided.

The substrate assembly preferably has a quadrangular or substantially quadrangular main surface, and the ninth step includes the steps of forming a first groove having a first depth along a long side of the quadrangle and forming a second groove having a second depth smaller than the first depth along a short side of the quadrangle.

A tenth step of firing the substrate assembly prior to the ninth step preferably is further provided.

Preferably, the fifth step includes the step of filling the plurality of first via holes with a first conductive material, and the seventh step includes the step of filling the plurality of second via holes with a second conductive material.

Preferably, the substrate assembly has a thickness not greater than about 0.6 mm, for example.

The above and other elements, features, steps, characteristics and advantages of the present invention will become more apparent from the following detailed description of the preferred embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an exploded view showing a disassembled state of a stack-type inductor element according to a preferred embodiment of the present invention.

FIG. 2A is a plan view showing one example of a ceramic sheet SH1 of a stack-type inductor element.

FIG. 2B is a plan view showing one example of a ceramic sheet SH3 of the stack-type inductor element.

FIG. 3A is an illustrative diagram showing one example of a pad electrode provided on a lower surface of ceramic sheet SH1.

FIG. 3B is a plan view showing one example of a ceramic sheet SH4 of the stack-type inductor element.

FIG. 4 is a perspective view showing appearance of the stack-type inductor element according to a preferred embodiment of the present invention.

FIG. 5 is a cross-sectional view along A-A' of the stack-type inductor element shown in FIG. 4.

FIG. 6A is a process chart showing a portion of a process for manufacturing ceramic sheet SH1.

FIG. 6B is a process chart showing another portion of the process for manufacturing ceramic sheet SH1.

FIG. 7A is a process chart showing still another portion of the process for manufacturing ceramic sheet SH1.

FIG. 7B is a process chart showing yet another portion of the process for manufacturing ceramic sheet SH1.

FIG. 8A is a process chart showing a portion of a process for manufacturing a ceramic sheet SH2.

FIG. 8B is a process chart showing another portion of the process for manufacturing ceramic sheet SH2.

FIG. 8C is a process chart showing still another portion of the process for manufacturing ceramic sheet SH2.

FIG. 9A is a process chart showing a portion of a process for manufacturing ceramic sheet SH3.

FIG. 9B is a process chart showing another portion of the process for manufacturing ceramic sheet SH3.

FIG. 10A is a process chart showing still another portion of the process for manufacturing ceramic sheet SH3.

FIG. 10B is a process chart showing yet another portion of the process for manufacturing ceramic sheet SH3.

FIG. 11A is a process chart showing a portion of a process for manufacturing ceramic sheet SH4.

FIG. 11B is a process chart showing another portion of the process for manufacturing ceramic sheet SH4.

FIG. 12 is a plan view showing one example of a carrier film on which a pad electrode is printed.

FIG. 13A is a process chart showing a portion of a process for manufacturing a stack-type inductor element.

FIG. 13B is a process chart showing another portion of the process for manufacturing a stack-type inductor element.

FIG. 13C is a process chart showing still another portion of the process for manufacturing a stack-type inductor element.

FIG. 14A is a process chart showing yet another portion of the process for manufacturing a stack-type inductor element.

FIG. 14B is a process chart showing another portion of the process for manufacturing a stack-type inductor element.

FIG. 14C is a process chart showing still another portion of the process for manufacturing a stack-type inductor element.

FIG. 14D is a process chart showing yet another portion of the process for manufacturing a stack-type inductor element.

FIG. 15A is a process chart showing a portion of a process for manufacturing ceramic sheet SH1 according to another preferred embodiment of the present invention.

FIG. 15B is a process chart showing another portion of the process for manufacturing ceramic sheet SH1 according to another preferred embodiment of the present invention.

FIG. 16A is a process chart showing still another portion of the process for manufacturing ceramic sheet SH1 according to another preferred embodiment of the present invention.

FIG. 16B is a process chart showing yet another portion of the process for manufacturing ceramic sheet SH1 according to another preferred embodiment of the present invention.

FIG. 17A is a process chart showing a portion of a process for manufacturing ceramic sheet SH2 according to another preferred embodiment of the present invention.

FIG. 17B is a process chart showing another portion of the process for manufacturing ceramic sheet SH2 according to another preferred embodiment of the present invention.

FIG. 18A is a process chart showing still another portion of the process for manufacturing ceramic sheet SH2 according to another preferred embodiment of the present invention.

FIG. 18B is a process chart showing yet another portion of the process for manufacturing ceramic sheet SH2 according to another preferred embodiment of the present invention.

FIG. 19A is a process chart showing a portion of a process for manufacturing ceramic sheet SH3 according to another preferred embodiment of the present invention.

FIG. 19B is a process chart showing another portion of the process for manufacturing ceramic sheet SH3 according to another preferred embodiment of the present invention.

FIG. 20A is a process chart showing still another portion of the process for manufacturing ceramic sheet SH3 according to another preferred embodiment of the present invention.

FIG. 20B is a process chart showing yet another portion of the process for manufacturing ceramic sheet SH3 according to another preferred embodiment of the present invention.

FIG. 21A is a process chart showing a portion of a process for manufacturing ceramic sheet SH4 according to another preferred embodiment of the present invention.

FIG. 21B is a process chart showing another portion of the process for manufacturing ceramic sheet SH4 according to another preferred embodiment of the present invention.

FIG. 22A is a process chart showing a portion of a process for manufacturing a stack-type inductor element according to another preferred embodiment of the present invention.

FIG. 22B is a process chart showing another portion of the process for manufacturing a stack-type inductor element according to another preferred embodiment of the present invention.

FIG. 22C is a process chart showing still another portion of the process for manufacturing a stack-type inductor element according to another preferred embodiment of the present invention.

FIG. 23A is a process chart showing yet another portion of the process for manufacturing a stack-type inductor element according to another preferred embodiment of the present invention.

FIG. 23B is a process chart showing another portion of the process for manufacturing a stack-type inductor element according to another preferred embodiment of the present invention.

FIG. 23C is a process chart showing still another portion of the process for manufacturing a stack-type inductor element according to another preferred embodiment of the present invention.

FIG. 24 is an exploded view showing a disassembled state of a stack-type inductor element according to yet another preferred embodiment of the present invention.

FIG. 25 is an explanatory diagram of a first example of alignment of pad electrodes provided on a lowermost surface and an uppermost surface of the stack-type inductor element.

FIG. 26 is an explanatory diagram of a second example of alignment of the pad electrodes provided on the lowermost surface and the uppermost surface of the stack-type inductor element.

FIG. **27** is an explanatory diagram of a third example of alignment of the pad electrodes provided on the lowermost surface and the uppermost surface of the stack-type inductor element.

FIG. **28** is an explanatory diagram of a fourth example of alignment of the pad electrodes provided on the lowermost surface and the uppermost surface of the stack-type inductor element.

FIG. **29** is an explanatory diagram of a fifth example of alignment of the pad electrodes provided on the lowermost surface and the uppermost surface of the stack-type inductor element.

FIG. **30** is a perspective transparent view of a communication device.

FIG. **31** is an explanatory diagram of a manner of generation of magnetic field from a stack-type inductor element included in the communication device.

FIG. **32** is a circuit diagram of the communication device.

FIG. **33** is a conceptual diagram of an SD card including a stack-type inductor element.

FIG. **34** is an explanatory diagram of a manner of introduction of an SD card including a stack-type inductor element in equipment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1**, a stack-type inductor element **10** according to a preferred embodiment of the present invention includes ceramic sheets SH**1** to SH**4** to define an antenna element for wireless communication in a 13.56 MHz band, for example, and stacked such that each main surface defines a quadrangular or substantially quadrangular shape. Ceramic sheets SH**1** to SH**4** preferably are equal or substantially equal in size of each main surface. Ceramic sheets SH**1** and SH**4** include a non-magnetic element, whereas ceramic sheets SH**2** to SH**3** include a magnetic element.

Consequently, a stack **12** defines a parallelepiped. Ceramic sheets SH**2** to SH**3** define a magnetic element layer **12***a*, ceramic sheet SH**1** defines a non-magnetic element layer **12***b*, and ceramic sheet SH**4** defines a non-magnetic element layer **12***c*. The stack **12** of the stack-type inductor element **10** has a stack structure such that magnetic element layer **12***a* is sandwiched between non-magnetic element layers **12***b* and **12***c*. A long side and a short side of the quadrangle defining the main surface (e.g., an upper surface or a lower surface) of stack **12** extend along an X axis and a Y axis respectively, and a thickness of stack **12** increases along a Z axis.

As shown in FIGS. **2**A to **2**B, five linear conductors **16** are provided on an upper surface of ceramic sheet SH**1**, and six linear conductors **18** are provided on an upper surface of ceramic sheet SH**3**. In addition, as shown in FIGS. **3**A to **3**B, twelve pad electrodes **14***a* are provided on a lower surface of ceramic sheet SH**1**, and twelve pad electrodes **14***b* are provided on an upper surface of ceramic sheet SH**4**. It is noted that no linear conductor is present on an upper surface of ceramic sheet SH**2** and a magnetic element appears over the entire upper surface.

Referring to FIG. **2**A, linear conductors **16** defining a portion of a coil conductor pattern are aligned at a distance D**1** in a direction of the X axis in a position extending obliquely to the Y axis. Opposing ends in a direction of length of linear conductor **16** remain inside of opposing ends in a direction of the Y axis of the upper surface of ceramic sheet SH**1**. Two linear conductors **16** and **16** on opposing sides in the direction of the X axis are arranged inside of the opposing ends in the direction of the X axis of the upper surface of ceramic sheet SH**1**.

Referring to FIG. **2**B, linear conductors **18** defining a portion of a coil conductor pattern are aligned at distance D**1** in the direction of the X axis in a position extending along the Y axis. Opposing ends in a direction of length of linear conductor **18** also remain inside of the opposing ends in the direction of the Y axis of the upper surface of ceramic sheet SH**3**. Two linear conductors **18** and **18** on opposing sides in the direction of the X axis are also arranged inside of the opposing ends in the direction of the X axis of the upper surface of ceramic sheet SH**3**.

A distance in the direction of the X axis from one end to the other end of linear conductor **16** corresponds to "D**1**". A position of one end of linear conductor **16** is adjusted to a position coinciding with one end of linear conductor **18** when viewed in a direction of the Z axis, and a position of the other end of linear conductor **16** is adjusted to a position coinciding with the other end of linear conductor **18** when viewed in the direction of the Z axis. The number of linear conductors **16** is smaller by one than the number of linear conductors **18**.

Therefore, when viewed in the direction of the Z axis, linear conductors **16** and **18** are alternately aligned in the direction of the X axis. In addition, one end of linear conductor **16** coincides with one end of linear conductor **18**, and the other end of linear conductor **16** coincides with the other end of linear conductor **18**.

Referring to FIG. **3**A, twelve pad electrodes **14***a* each include a main surface with a rectangular or substantially rectangular shape and they are equal or substantially equal to one another in a size of the main surface. Among these, six pad electrodes **14***a* extend at an equal or substantially equal interval along the X axis slightly inside of an end portion on a positive side in the direction of the Y axis, and six remaining pad electrodes **14***a* extend at an equal or substantially equal interval along the X axis slightly inside of an end portion on a negative side in the direction of the Y axis.

A distance from pad electrode **14***a* present on a most negative side in the direction of the X axis to the end portion on the negative side in the direction of the X axis of ceramic sheet SH**1** is equal or substantially equal to a distance from pad electrode **14***a* present on a most positive side in the direction of the X axis to the end portion on the positive side in the direction of the X axis of ceramic sheet SH**1**. A distance from pad electrode **14***a* present on the most negative side in the direction of the Y axis to the end portion on the negative side in the direction of the Y axis of ceramic sheet SH**1** is equal or substantially equal to a distance from pad electrode **14***a* present on the most positive side in the direction of the Y axis to the end portion on the positive side in the direction of the Y axis of ceramic sheet SH**1**.

Therefore, with a straight line extending along the X axis through the center in the direction of the Y axis of the main surface of ceramic sheet SH**1** being defined as the reference, six pad electrodes **14***a* on the negative side in the direction of the Y axis relative to this straight line are configured in line symmetry to six pad electrodes **14***a* on the positive side in the direction of the Y axis relative to this straight line.

With a straight line extending along the Y axis through the center in the direction of the X axis of the main surface of ceramic sheet SH**1** being defined as the reference, six pad electrodes **14***a* on the negative side in the direction of the X axis relative to this straight line are configured in line symmetry to six pad electrodes **14***a* on the positive side in the direction of the X axis relative to this straight line.

Referring to FIG. **3**B, twelve pad electrodes **14***b* each include a main surface with a rectangular or substantially rectangular shape and they are equal or substantially equal to one another in a size of the main surface. Among these, six pad electrodes **14***b* extend at an equal or substantially equal interval along the X axis slightly inside of an end portion on a positive side in the direction of the Y axis, and six remaining pad electrodes **14***b* extend at an equal or substantially equal interval along the X axis slightly inside of an end portion on a negative side in the direction of the Y axis.

A distance from pad electrode **14***b* present on a most negative side in the direction of the X axis to the end portion on the negative side in the direction of the X axis of ceramic sheet SH**4** is equal or substantially equal to a distance from pad electrode **14***b* present on a most positive side in the direction of the X axis to the end portion on the positive side in the direction of the X axis of ceramic sheet SH**4**. A distance from pad electrode **14***b* present on the most negative side in the direction of the Y axis to the end portion on the negative side in the direction of the Y axis of ceramic sheet SH**4** is equal to a distance from pad electrode **14***b* present on the most positive side in the direction of the Y axis to the end portion on the positive side in the direction of the Y axis of ceramic sheet SH**4**.

Therefore, with a straight line extending along the X axis through the center in the direction of the Y axis of the main surface of ceramic sheet SH**4** being defined as the reference, six pad electrodes **14***b* on the negative side in the direction of the Y axis relative to this straight line are configured in line symmetry to six pad electrodes **14***b* on the positive side in the direction of the Y axis relative to this straight line.

With a straight line extending along the Y axis through the center in the direction of the X axis of the main surface of ceramic sheet SH**4** being defined as the reference, six pad electrodes **14***b* on the negative side in the direction of the X axis relative to this straight line are configured in line symmetry to six pad electrodes **14***b* on the positive side in the direction of the X axis relative to this straight line.

A size of the main surface of pad electrode **14***b* is also the same or substantially the same as a size of the main surface of pad electrode **14***a*, and a manner of arrangement of pad electrodes **14***b* at the main surface of ceramic sheet SH**4** is the same as a manner of arrangement of pad electrodes **14***a* at the main surface of ceramic sheet SH**1**. Therefore, pad electrodes **14***b* are configured in mirror symmetry to pad electrodes **14***a*. When viewed in the direction of the Z axis, opposing ends of each linear conductor **18** coincide with two pad electrodes **14***a* and **14***a* aligned along the Y axis, and further coincide also with two pad electrodes **14***b* and **14***b* aligned along the Y axis.

Referring back to FIG. **1**, via hole conductors **20***a* pass through magnetic element layer **12***a* in the direction of the Z axis at a position of one end of linear conductors **16** (the end portion on the positive side in the direction of the Y axis). Via hole conductors **20***b* pass through magnetic element layer **12***a* in the direction of the Z axis at a position of the other end of linear conductors **16** (the end portion on the negative side in the direction of the Y axis). This via hole conductor **20***a* defines a portion of a coil conductor pattern.

Linear conductors **16** are configured in a manner shown in FIG. **2**A, and linear conductors **18** are configured in a manner shown in FIG. **2**B. Therefore, via hole conductors **20***a* are connected to one ends (the end portion on the positive side in the direction of the Y axis) of five linear conductors **18** starting from the negative side in the direction of the X axis at the upper surface of ceramic sheet SH**3**. Via hole conductors **20***b* are connected to the other ends (the end portion on the negative side in the direction of the Y axis) of five linear conductors **18** starting from the positive side in the direction of the X axis at the upper surface of ceramic sheet SH**3**.

Consequently, linear conductors **16** and linear conductors **18** are spirally connected, and thus a coil conductor (a wound element) having the X axis as an axis of winding is provided. Since a magnetic element is present inside the coil conductor, the coil conductor defines and functions as an inductor. In this case, a portion of ceramic sheets SH**2** and SH**3** which are the magnetic element layers defines and serves as a magnetic element core.

A via hole conductor **22***a* passes through magnetic element layer **12***a* and non-magnetic element layer **12***b* in the direction of the Z axis at a position of one end of linear conductor **18** present on the most positive side in the direction of the X axis. Similarly, a via hole conductor **22***b* passes through magnetic element layer **12***a* and non-magnetic element layer **12***b* in the direction of the Z axis at a position of the other end of linear conductor **18** present on the most negative side in the direction of the X axis.

Via hole conductor **22***a* is connected to pad electrode **14***a* present on the most positive side in the direction of the X axis and on the positive side in the direction of the Y axis. Via hole conductor **22***b* is connected to pad electrode **14***a* present on the most negative side in the direction of the X axis and on the negative side in the direction of the Y axis. Thus, two different points of the inductor are connected to two pad electrodes **14***a* and **14***a*, respectively.

Stack **12**, that is, stack-type inductor element **10**, thus fabricated has appearance shown in FIG. **4**. A cross-section along A-A' of this stack-type inductor element **10** has a structure shown in FIG. **5**.

It is noted that ceramic sheets SH**1** and SH**4** preferably are made of a non-magnetite ferrite material (relative permeability: 1) and exhibit a value for coefficient of thermal expansion in a range from about 8.5 to about 9.0, for example. Ceramic sheets SH**2** to SH**3** preferably are made of a magnetite ferrite material (relative permeability: 100 to 120) and exhibit a value for coefficient of thermal expansion in a range from about 9.0 to about 10.0, for example. Pad electrodes **14***a* and **14***b*, linear conductors **16** and **18**, and via hole conductors **20***a* to **20***b* and **22***a* to **22***b* preferably are made of a silver material and exhibit a coefficient of thermal expansion of about 20.

Ceramic sheet SH**1** is fabricated in a manner shown in FIGS. **6**A to **6**B and FIGS. **7**A to **7**B. Initially, a ceramic green sheet made of a non-magnetic ferrite material is prepared as a mother sheet BS**1** (see FIG. **6**A). Here, a plurality of dashed lines extending in the direction of the X axis and the direction of the Y axis show cutting positions. Each of a plurality of rectangles defined by these dashed lines is defined as a "division unit".

Then, a plurality of through holes HL**1** are formed in mother sheet BS**1** in correspondence with the vicinity of an intersection of the dashed lines (see FIG. **6**B), and through hole HL**1** is filled with a conductive paste PS**1** (see FIG. **7**A). Conductive paste PS**1** forms via hole conductor **22***a* or **22***b*. When filling with conductive paste PS**1** is completed, a conductor pattern corresponding to linear conductors **16** is printed on an upper surface of mother sheet BS**1** (see FIG. **7**B).

Ceramic sheet SH**2** is fabricated in a manner shown in FIGS. **8**A to **8**C. Initially, a ceramic green sheet made of a magnetic ferrite material is prepared as a mother sheet BS**2** (see FIG. **8**A). Here, a plurality of dashed lines extending in the direction of the X axis and the direction of the Y axis show cutting positions. Then, a plurality of through holes HL**2** are formed in mother sheet BS**2** along the dashed lines extending in the direction of the X axis (see FIG. **8**B), and through hole HL**2** is filled with a conductive paste PS**2** forming via hole conductor **20***a*, **20***b*, **22***a*, or **22***b* (see FIG. **8**C).

Ceramic sheet SH**3** is fabricated in a manner shown in FIGS. **9**A to **9**B and FIGS. **10**A to **10**B. Initially, a ceramic green sheet made of a magnetic ferrite material is prepared as a mother sheet BS**3** (see FIG. **9**A). Here, a plurality of dashed lines extending in the direction of the X axis and the direction of the Y axis show cutting positions.

Then, a plurality of through holes HL**3** are formed in mother sheet BS**3** along the dashed lines extending in the direction of the X axis (see FIG. **9**B), and through hole HL**3** is filled with a conductive paste PS**3** (see FIG. **10**A). Conductive paste PS**3** forms via hole conductor **20***a*, **20***b*, **22***a*, or **22***b*. When filling with conductive paste PS**3** is completed, a conductor pattern corresponding to linear conductors **18** is printed on an upper surface of mother sheet BS**3** (see FIG. **10**B).

Ceramic sheet SH**4** is fabricated in a manner shown in FIGS. **11**A to **11**B. Initially, a ceramic green sheet made of a non-magnetic ferrite material is prepared as a mother sheet BS**4** (see FIG. **11**A). Here, a plurality of dashed lines extending in the direction of the X axis and the direction of the Y axis show cutting positions. Then, a conductor pattern corresponding to pad electrodes **14***b* is printed on an upper surface of mother sheet BS**4** (see FIG. **11**B).

The conductor pattern corresponding to pad electrodes **14***a* is printed on a carrier film **24** in a manner shown in FIG. **12**. A size of a main surface of carrier film **24** is the same or substantially the same as a size of the main surface of mother sheets BS**1** to BS**4**. A plurality of dashed lines extending in the direction of the X axis and the direction of the Y axis correspond to a plurality of dashed lines drawn on mother sheets BS**1** to BS**4**. Mother sheets BS**1** to BS**4** created in the manner described above are stacked and press-bonded in this order (see FIG. **13**A). Here, a position of stack of each sheet is adjusted such that dashed lines allocated to each sheet coincide when viewed in the direction of the Z axis. In succession, carrier film **24** shown in FIG. **12** is prepared (see FIG. **13**B) and a conductor pattern formed on carrier film **24** is transferred to the lower surface of mother sheet BS**1** (see FIG. **13**C).

As transfer of the conductor pattern is completed, carrier film **24** is peeled off (see FIG. **14**A), and an unprocessed substrate assembly is fabricated. A thickness of the fabricated substrate assembly preferably is suppressed to about 0.6 mm or smaller, for example. The fabricated substrate assembly is fired (see FIG. **14**B) and thereafter subjected to primary scribing and secondary scribing (see FIGS. **14**C to **14**D).

In primary scribing, a blade of a scriber **26** is applied along the dashed line extending in the direction of the X axis, and in secondary scribing, the blade of scriber **26** is applied along the dashed line extending in the direction of the Y axis. In any of primary scribing and secondary scribing, a groove is formed in an upper surface of the substrate assembly. It is noted that a groove formed in primary scribing reaches non-magnetic element layer **12***b*, whereas a groove formed in secondary scribing reaches only magnetic element layer **12***a*. This is a groove made by prior crack which was caused by adjusting a blade pressure at the time of application of the blade of scriber **26** and intentionally adjusting a depth. As scribing is completed, the substrate assembly is broken into division units, to obtain a plurality of stack-type inductor elements **10**.

As can be seen from the description above, stack **12** includes magnetic element layer **12***a* and non-magnetic element layers **12***b* and **12***c* provided on respective opposing main surfaces thereof. Linear conductors **16** and **18** define a portion of an inductor having a longitudinal direction of stack **12** as an axis of winding and are provided on opposing main surfaces of magnetic element layer **12***a*. Pad electrodes **14***a* are provided on the upper surface of stack **12**, and pad electrodes **14***b* are provided on the lower surface of stack **12** so as to be symmetric to pad electrodes **14***a*. Two different points of the inductor are electrically connected to two different pad electrodes **14***a* and **14***a*, respectively.

Stack-type inductor element **10** is manufactured by breaking a substrate assembly having a structure such that magnetic mother sheets BS**2** and BS**3** are sandwiched between non-magnetic mother sheets BS**1** and BS**4** into division units. The substrate assembly is fabricated in a manner below.

Initially, through holes HL**1** extending in the direction of the Z axis are formed in mother sheet BS**1** (see FIG. **6**B), and a conductor pattern corresponding to linear conductors **16** is formed on the upper surface of mother sheet BS**1** (see FIG. **7**B). In addition, through holes HL**2** extending in the direction of the Z axis are formed in mother sheet BS**2** (see FIG. **8**B), through holes HL**3** extending in the direction of the Z axis are formed in mother sheet BS**3** (see FIG. **9**B), and a conductor pattern corresponding to linear conductors **18** is formed on the upper surface of mother sheet BS**3** (see FIG. **10**B).

Carrier film **24** on which a plurality of pad electrodes **14***a* are printed is prepared on the lower surface of mother sheet BS**1**, and two pad electrodes **14***a* and **14***a* defining each division unit are connected to two points of linear conductors **16** through two corresponding through holes HL**1** and HL**1**, respectively (see FIG. **13**C). It is noted that pad electrodes **14***b* are formed on the upper surface of mother sheet BS**4** so as to be symmetric to pad electrodes **14***a* (see FIG. **11**B). The inductor is formed by spirally connecting linear conductors **16** and **18** for each division unit through through holes HL**2** and HL**3** (see FIG. **13**A).

The substrate assembly thus fabricated is subjected to primary scribing and secondary scribing after firing (see FIGS. **14**B to **14**D), and broken along grooves formed by such scribing.

In the fired substrate assembly, residual stress originating from a difference in coefficient of thermal expansion between a material forming pad electrodes **14***a* and **14***b* and linear conductors **16** and **18** and a material forming magnetic element layer **12***a* or non-magnetic element layers **12***b* and **12***c* is caused. It is noted that pad electrodes **14***a* and **14***b* formed on the opposing main surfaces of stack **12** are mirror symmetric to each other in this preferred embodiment. Therefore, warpage of the substrate assembly originating from residual stress is significantly reduced or prevented and stack-type inductor element **10** obtained by breakage is significantly smaller in thickness.

It is noted that decrease in thickness is suitable for a case that stack-type inductor element **10** is contained in an SIM card or a micro SIM card together with a secure IC for NFC (Near Field Communication), for example.

Since residual stress is generated, a breakage line runs in a direction of thickness of stack **12** so as to go around pad electrodes **14***a* and **14***b*. Thus, defective breakage is significantly decreased or prevented.

Furthermore, since no groove is present in a stage prior to firing, a magnetic element layer is not exposed and precipitation of plating onto a magnetic element layer is avoided. By making use of dummy pad electrode **14***a* (pad electrode **14***a* not connected to an inductor) to solder to mount stack-type inductor element **10** on a printed board, the number of points of contact between stack-type inductor element **10** and the printed board increases. Thus, fall strength or bending strength of stack-type inductor element **10** is enhanced.

In succession, a method of manufacturing stack-type inductor element **10** in another preferred embodiment will be described. Ceramic sheet SH**1** is fabricated in a manner shown in FIGS. **15**A to **15**B and FIGS. **16**A to **16**B. Initially, a ceramic green sheet made of a non-magnetic ferrite material is prepared as a mother sheet BS**1'** (see FIG. **15**A). Here, a plurality of dashed lines extending in the direction of the X axis and the direction of the Y axis show cutting positions.

Then, a plurality of through holes HL**1'** are formed in mother sheet BS**1'** in correspondence with the vicinity of an intersection of the dashed lines (see FIG. **15**B), and through hole HL**1'** is filled with a conductive paste PS**1'** (see FIG. **16**A). Conductive paste PS**1'** forms via hole conductor **22***a* or **22***b*. When filling with conductive paste PS**1'** is completed, a conductor pattern corresponding to pad electrodes **14***a* is printed on a lower surface of mother sheet BS**1'** (see FIG. **16**B).

Ceramic sheet SH**2** is fabricated in a manner shown in FIGS. **17**A to **17**B and FIGS. **18**A to **18**B. Initially, a ceramic green sheet made of a magnetic ferrite material is prepared as a mother sheet BS**2'** (see FIG. **17**A). Here, a plurality of dashed lines extending in the direction of the X axis and the direction of the Y axis show cutting positions. Then, a plurality of through holes HL**2'** are formed in mother sheet BS**2'** along a dashed line extending in the direction of the X axis (see FIG. **17**B), and through hole HL**2'** is filled with a conductive paste PS**2'** forming via hole conductor **20***a*, **20***b*, **22***a*, or **22***b* (see FIG. **18**A). When filling with conductive paste PS**2'** is completed, a conductor pattern corresponding to linear conductors **16** is printed on a lower surface of mother sheet BS**2'** (see FIG. **18**B).

Ceramic sheet SH**3** is fabricated in a manner shown in FIGS. **19**A to **19**B and FIGS. **20**A to **20**B. Initially, a ceramic green sheet made of a magnetic ferrite material is prepared as a mother sheet BS**3'** (see FIG. **19**A). Here, a plurality of dashed lines extending in the direction of the X axis and the direction of the Y axis show cutting positions.

Then, a plurality of through holes HL**3'** are formed in mother sheet BS**3'** along the dashed line extending in the direction of the X axis (see FIG. **19**B), and through hole HL**3'** is filled with a conductive paste PS**3'** (see FIG. **20**A). Conductive paste PS**3'** forms via hole conductor **20***a*, **20***b*, **22***a*, or **22***b*. When filling with conductive paste PS**3'** is completed, a conductor pattern corresponding to linear conductors **18** is printed on an upper surface of mother sheet BS**3'** (see FIG. **20**B).

Ceramic sheet SH**4** is fabricated in a manner shown in FIGS. **21**A to **21**B. Initially, a ceramic green sheet made of a non-magnetic ferrite material is prepared as a mother sheet BS**4'** (see FIG. **21**A). Here, a plurality of dashed lines extending in the direction of the X axis and the direction of the Y axis show cutting positions. Then, a conductor pattern corresponding to pad electrodes **14***b* is printed on an upper surface of mother sheet BS**4'** (see FIG. **21**B).

Mother sheets BS**1'** and BS**2'** are stacked and press-bonded in such a position that a lower surface of mother sheet BS**2'** faces the upper surface of mother sheet BS**1'** (see FIG. **22**A). Here, a position of stack of each sheet is adjusted such that dashed lines allocated to each sheet coincide when viewed in the direction of the Z axis.

Similarly, mother sheets BS**3'** and BS**4'** are stacked and press-bonded in such a position that the upper surface of mother sheet BS**3'** faces a lower surface of mother sheet BS**4'** (see FIG. **22**B). Here again, a position of stack of each sheet is adjusted such that dashed lines allocated to each sheet coincide when viewed in the direction of the Z axis.

In succession, a vertical direction of the stack based on mother sheets BS**1'** and BS**2'** is inverted, and the stack based on mother sheets BS**3'** and BS**4'** is additionally stacked and press-bonded (see FIG. **22**C). Here, a position of stack is adjusted such that the lower surface of mother sheet BS**3'** faces the upper surface of mother sheet BS**2'** and dashed lines allocated to each sheet coincide when viewed in the direction of the Z axis. Thus, an unprocessed substrate assembly of which thickness is reduced to about 0.6 mm or smaller, for example, is fabricated. The fabricated substrate assembly is fired (see FIG. **23**A), and thereafter subjected to primary scribing and secondary scribing (see FIGS. **23**B to **23**C).

In primary scribing, a blade of scriber **26** is applied along the dashed line extending in the direction of the X axis, and in secondary scribing, the blade of scriber **26** is applied along the dashed line extending in the direction of the Y axis. In any of primary scribing and secondary scribing, a groove is formed in an upper surface of the substrate assembly. It is noted that a groove formed in primary scribing reaches non-magnetic element layer **12***b*, whereas a groove formed in secondary scribing reaches only magnetic element layer **12***a*. As scribing is completed, the substrate assembly is broken into division units to obtain a plurality of stack-type inductor elements **10**.

In this preferred embodiment as well, in the fired substrate assembly, residual stress originating from a difference in coefficient of thermal expansion between a material forming pad electrodes **14***a* and **14***b* and linear conductors **16** and **18** and a material forming magnetic element layer **12***a* or non-magnetic element layers **12***b* and **12***c* is caused. It is noted that pad electrodes **14***a* and **14***b* provided on the opposing main surfaces of stack **12** are mirror symmetric to each other and therefore warpage of the substrate assembly originating from residual stress is significantly decreased or prevented and stack-type inductor element **10** obtained by breakage is smaller in thickness.

It is noted that linear conductor **16** extends obliquely to the Y axis, whereas linear conductor **18** extends in the direction of the Y axis in the preferred embodiment described above. So long as linear conductors **16** and **18** are connected like a coil by via hole conductors **20***a* and **20***b*, however, a direction of extension of linear conductors **16** and **18** may be different from that in this preferred embodiment.

In addition, in the preferred embodiment described above, a conductor pattern corresponding to linear conductors **18** preferably is printed on the upper surface of mother sheet BS**3** or BS**3'**. The conductor pattern corresponding to linear conductor **18**, however, may be printed on the lower surface of mother sheet BS**4** or BS**4'**.

Moreover, in this preferred embodiment, ceramic sheets SH**2** and SH**3** are stacked to define magnetic element layer **12***a*. Magnetic element layer **12***a* may be formed, however, by stacking a plurality of ceramic sheets corresponding to magnetic element layer ceramic sheet SH**2** and ceramic sheet SH**3**.

In the preferred embodiment of the stack-type inductor element shown in FIGS. **1** to **5**, in forming a coil conductor pattern by stacking magnetic element layers, an axis of winding of this coil conductor pattern is parallel or substantially parallel to a main surface of the magnetic element layer, however, this is merely one example and it may be perpendicular or substantially perpendicular to the main surface of the magnetic element layer, for example, as shown in FIG. **24**. In an example shown in FIG. **24**, the axis of winding extends in a vertical direction in the figure.

In the example shown in FIG. **24**, non-magnetic element layer **12***b*, magnetic element layer **12***a*, non-magnetic element layer **12***b*, and non-magnetic element layer **12***b* are successively stacked from below. The stack as a whole preferably defines a parallelepiped. Two rows of pad electrodes **14***a* are arranged on a lower surface of non-magnetic element layer **12***b* located lowest in FIG. **24**. In FIG. **24**, for the sake of convenience of illustration, a manner of alignment of pad electrodes on the lower surface of non-magnetic element layer **12***b* located lowest is shown as being projected further below. A condition for alignment of these pad electrodes **14***a* is the same as described with reference to FIG. **3**A. Though six pad electrodes **14***a* are aligned along a longitudinal direction in FIG. **3**A, the number of pad electrodes **14***a* aligned along the longitudinal direction is five in the example shown in FIG. **24**. The number of pad electrodes **14***a* aligned in the longitudinal direction is shown merely by way of example, and the number is not limited thereto.

A helical in-plane conductor **19***a* is provided on an upper surface of magnetic element layer **12***a*. On an upper surface of non-magnetic element layer **12***b* adjacent to an upper side of magnetic element layer **12***a*, a helical in-plane conductor **19***b* is provided. It is noted that, when viewed in a direction of stack, in-plane conductor **19***a* and in-plane conductor **19***b* do not completely coincide with each other and they are different in position occupied. When viewed in the direction of stack, they satisfy such positional relation that one end of in-plane conductor **19***a* and one end of in-plane conductor **19***b* coincide with each other. On an upper surface of non-magnetic element layer **12***b* located highest in FIG. **24**, two rows of pad electrodes **14***b* are arranged. A condition for alignment of these pad electrodes **14***b* is the same as described with reference to FIG. **3**B. The number of pad electrodes **14***b* aligned in the longitudinal direction is shown merely by way of example and the number is not limited thereto.

One end of in-plane conductor **19***a* is electrically connected to one end of in-plane conductor **19***b* through a via hole conductor **20***c* provided to pass through non-magnetic element layer **12***b* adjacent to the upper side of magnetic element layer **12***a*. The other end of in-plane conductor **19***a* is electrically connected through another via hole conductor to a pad electrode **14***a***1** which is one of pad electrodes **14***a* provided on a lowermost surface. The other end of in-plane conductor **19***b* is electrically connected through yet another via hole conductor to a pad electrode **14***a***2** which is another one of pad electrodes **14***a* provided on the lowermost surface.

Consequently, in-plane conductor **19***a*, via hole conductor **20***c*, and in-plane conductor **19***b* are connected like a coil, so that a coil conductor having the axis of winding in the direction of stack is provided. The stack, that is, the stack-type inductor element, thus fabricated is substantially the same in appearance as shown in FIG. **4**. It is noted that, in FIG. **4**, two layers of ceramic sheets SH**2** and SH**3** were magnetic elements and hence a portion hatched with dots, which represents a magnetic element, appeared as a thickness of two layers on a side surface of the stack also in the perspective view. In FIG. **24**, however, single magnetic element layer **12***a* is provided, and hence a thickness of a magnetic element portion which appears on the side surface of the stack is different.

It is noted that an alignment pattern of pad electrodes provided on the lowermost surface and the uppermost surface of the stack is not limited to those as described so far. For example, the alignment pattern may be as shown in FIGS. **25** to **29**. In FIGS. **25** to **29**, for the sake of convenience of illustration, a manner of alignment of pad electrodes on the lower surface of non-magnetic element layer **12***b* located lowest is shown as being projected further below.

As shown in FIG. **25**, a plurality of pad electrodes **14***b* arranged on the uppermost surface of the stack may be of two mixed types of large and small. At opposing ends in the longitudinal direction, pad electrodes **14***b* each in a strip shape which extend in a direction of a short side of the stack are arranged, and pad electrodes **14***b* substantially in a square shape are arranged in an intermediate portion lying between two pad electrodes **14***b* each in a strip shape. This is also the case with a plurality of pad electrodes **14***a* arranged on the lowermost surface of the stack.

In the example shown in FIG. **25**, a plurality of pad electrodes **14***b* arranged on the uppermost surface of the stack are all electrically open regardless of a size. Two pad electrodes **14***a***1** and **14***a***2** each in a strip shape, which are located at the respective opposing ends in the longitudinal direction of the plurality of pad electrodes **14***a* arranged on the lowermost surface, are electrically connected to a coil conductor provided in the inside of the stack, and pad electrodes **14***a* other than those are electrically open.

As shown in FIG. **26**, all of the plurality of pad electrodes **14***b* arranged on the uppermost surface of the stack preferably have a strip shape extending in the direction of the short side of the stack. This is also the case with the plurality of pad electrodes **14***a* arranged on the lowermost surface of the stack.

In the example shown in FIG. **26**, the plurality of pad electrodes **14***b* arranged on the uppermost surface of the stack are all electrically open. Two pad electrodes **14***a***1** and **14***a***2** each in a strip shape, which are located at the respective opposing ends in the longitudinal direction of the plurality of pad electrodes **14***a* arranged on the lowermost surface, are electrically connected to the coil conductor provided inside of the stack, and pad electrodes **14** other than those are electrically open.

As shown in FIG. **27**, the number of pad electrodes **14***b* arranged on the uppermost surface of the stack may be set to two and only one pad electrode **14***b* may be arranged at each end in the longitudinal direction. Though pad electrode **14***b* preferably is strip shaped in this example, this is merely by way of example and the shape is not limited to a strip shape. This is also the case with the plurality of pad electrodes **14***a* arranged on the lowermost surface of the stack.

In the example shown in FIG. **27**, no pad electrode is arranged in a central portion on the uppermost surface and the lowermost surface of the stack. Such a construction is also acceptable. In the example shown in FIG. **27**, two pad electrodes **14***b* arranged on the uppermost surface of the stack are each electrically open. Two pad electrodes **14***a***1** and **14***a***2** each in a strip shape arranged on the lowermost surface are electrically connected to the coil conductor provided inside of the stack.

As shown in FIG. **28**, alignment or the number of pad electrodes may be different between the lowermost surface and the uppermost surface of the stack. In the example shown in FIG. **28**, on the lowermost surface, ten pad electrodes **14***a* in total are arranged in matrix of 2×5, whereas on the uppermost surface, six pad electrodes **14***b* in total are arranged in matrix of 2×3. The number may thus be different.

As shown in FIG. **29**, the number of pad electrodes may be smaller in the lowermost surface than in the uppermost surface. In the example shown in FIG. **29**, on the lowermost surface, six pad electrodes **14***a* in total are arranged in matrix of 2×3, whereas on the uppermost surface, ten pad electrodes **14***b* in total are arranged in matrix of 2×5.

In the examples shown in FIGS. **28** and **29**, the plurality of pad electrodes **14***b* arranged on the uppermost surface of the stack are all electrically open. Two pad electrodes **14***a***1** and **14***a***2** of the plurality of pad electrodes **14***a* arranged on the lowermost surface are electrically connected to the coil conductor provided inside of the stack, and pad electrodes **14***a* other than those are electrically open.

In FIGS. **28** and **29**, how magnetic element layer **12***a* and non-magnetic element layer **12***b* appear on the side surface is different from that in FIGS. **25** to **27**. In accordance with change in construction of pad electrodes on the uppermost surface or the lowermost surface of the stack, how they are aligned or a ratio of thickness may be varied as appropriate between the magnetic element layer and the non-magnetic element layer in a thickness of the stack as a whole.

The number of magnetic element layers **12***a* and non-magnetic element layers **12***b* included in the stack shown in the drawings by way of example only and limitation thereto is not intended in each preferred embodiment described so far. In addition, a non-magnetic element layer does not necessarily have to be provided and all layers in the stack may be defined by magnetic element layers.

As already described, the stack described so far preferably is a stack-type inductor element. Such a stack-type inductor element can be used, for example, as an antenna element for wireless communication. Exemplary usage thereof will be described below.

FIG. **30** shows one example of a communication device. This communication device is a portable communication terminal **51**. FIG. **30** is a perspective transparent diagram of portable communication terminal **51** mainly viewed from a back side. Portable communication terminal **51** includes a housing **52**. In FIG. **30**, a back side portion **52***b* which is a portion of housing **52** is seen in an upper side. A printed circuit board **53** is accommodated in housing **52**. In the vicinity of one side of printed circuit board **53**, a stack-type inductor element **54** constructed as described so far is located. In this example, stack-type inductor element **54** is placed in a surface facing the back side of portable communication terminal **51**, of two main surfaces of printed circuit board **53**. A stack-type inductor element having an axis of winding in the longitudinal direction of the stack like stack-type inductor element **10** shown in FIGS. **1** to **5** was used as stack-type inductor element **54**. FIG. **31** shows portable communication terminal **51** viewed from a side. Housing **52** includes a front side portion **52***a* and back side portion **52***b*. Stack-type inductor element **54** placed at an end portion of printed circuit board **53** generates magnetic field intensity distribution as shown in FIG. **31**. This magnetic field allows portable communication terminal **51** to establish near field communication (also referred to as "NFC"). It is noted that a circuit as shown in FIG. **32** is configured in portable communication terminal **51** serving as the communication device. Namely, this communication device includes stack-type inductor element **54** and a radio frequency integrated circuit (also referred to as an "RFIC") **55**. When viewed from RFIC **55**, a capacitor **56** is connected electrically in parallel to stack-type inductor element **54**.

FIG. **33** shows one example of an SD card. An SD card **58** includes printed circuit board **53** and stack-type inductor element **54** which can be used as an antenna element. A stack-type inductor element having an axis of winding in the direction of the short side of the stack was used as this stack-type inductor element **54**. As shown in FIG. **34**, as SD card **58** is introduced in equipment **59**, equipment **59** can establish external communication based on NFC. Even though equipment **59** does not include an antenna for NFC, equipment **59** can be used as equipment including an antenna for NFC by introducing SD card **58** in equipment **59**. Instead of being any card based on SD specifications, SD card **58** may be a flash memory card complying with other specifications similar thereto.

Although preferred embodiments of the present invention has been described and illustrated in detail, it should be clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the scope of the present invention being interpreted by the terms of the appended claims.

While preferred embodiments of the present invention have been described above, it is to be understood that variations and modifications will be apparent to those skilled in the art without departing from the scope and spirit of the present invention. The scope of the present invention, therefore, is to be determined solely by the following claims.

What is claimed is:

1. A stack-type inductor element, comprising:

a stack including a magnetic element layer, a first main surface, and a second main surface;

a coil conductor pattern provided in the stack and including the magnetic element layer as a magnetic element core;

a plurality of first pad electrodes provided on the first main surface of the stack; and

a plurality of second pad electrodes provided on the second main surface of the stack to include a portion symmetric to the plurality of first pad electrodes; wherein

a first end and a second end of the coil conductor pattern is electrically connected to two of the plurality of first pad electrodes, respectively, and the plurality of second pad electrodes are all electrically open;

the first and second main surfaces of the stack oppose each other, and the opposing first and second main surfaces include portions that are symmetric to each other; and

the stack is an integral fired ceramic laminate, and the first and second main surfaces of the stack respectively define uppermost and lowermost surfaces of the ceramic laminate.

2. The stack-type inductor element according to claim **1**, wherein the stack has a rectangular or substantially rectangular shape when viewed in a direction of stack of the stack and the plurality of first pad electrodes are arranged in two rows along a longitudinal direction of the stack.

3. The stack-type inductor element according to claim **1**, wherein a number of the first pad electrodes is three or more and a pad electrode not connected to the coil conductor pattern of the plurality of first pad electrodes is electrically open.

4. The stack-type inductor element according to claim **1**, wherein

the stack includes non-magnetic element layers superimposed on opposing main surfaces of the magnetic element layer.

5. The stack-type inductor element according to claim **1**, wherein

the coil conductor pattern has an axis of winding in a direction in parallel or substantially parallel to a main surface of the magnetic element layer.

6. The stack-type inductor element according to claim **5**, wherein the stack has a rectangular or substantially rectangular shape when viewed in a direction of stack of the stack and the axis of winding is parallel or substantially parallel to a longitudinal direction of the rectangular or substantially rectangular shape.

7. The stack-type inductor element according to claim **1**, wherein

the coil conductor pattern defines a coil antenna.

8. A communication device, comprising:

the stack-type inductor element according to claim **7**; and

a radio frequency integrated circuit.

9. The communication device according to claim **8**, wherein the stack has a thickness not greater than about 0.6 mm.

10. The stack-type inductor element according to claim **1**, wherein the stack has a thickness not greater than about 0.6 mm.

11. The stack-type inductor element according to claim **1**, wherein the stack includes further magnetic element layers superimposed on opposing main surfaces of the magnetic element layer as the magnetic element core, the further magnetic element layers defining the first main surface and the second main surface of the stack.

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